

A
NEW METHOD
OF
CHEMISTRY;

INCLUDING THE
History, Theory, and Practice
of the ART:

Translated from the ORIGINAL LATIN of
Dr. B O E R H A A V E's
ELEMENTA CHEMIÆ,

AS PUBLISHED BY HIMSELF.

To which are added,

NOTES; and an APPENDIX,
SHEWING
The NECESSITY and UTILITY of
Enlarging the Bounds of CHEMISTRY.
WITH SCULPTURES.

By PETER SHAW, M. D. F.R.S.

THE THIRD EDITION Corrected.

L O N D O N:

Printed for T. and T. LONGMAN, in Paternoster-Row.
MDCCLIII.

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OF THE ART

History, Theory, and Practice
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2299
ELEMENTARY CHEMISTRY

NOTES and an APPENDIX
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Advertisement.

OUR New Method of Chemistry being out of print,
it was thought proper to give a fresh translation of
Dr. Boerhaave's *Elementa Chemiæ*, rather than publish
the former book again. Most of the notes made use of in
our first edition, are here preserved; and several others;
are added, where they seemed to be necessary. An Ap-
pendix also is added, to shew the way of carrying the Art
still farther.

P. S.

The AUTHOR to his Brother

JAMES BOERHAAVE.

THE constraint I am under of publishing this work, has obliged me, in my old age, to review many of the labours of my youth: and in the course thereof, I have sometimes been led to wonder, both at the number of the experiments I have made, and the great danger that attended them. In both which, however, I had the pleasure to find you my constant associate. You have not forgot how many days and nights we have spent together, in the chemical examination of natural bodies; at the time when your chief view was to Medicine, and mine to Theology.

Providence indeed has disposed of us otherwise; and exchanging our views, consigned you to the service of religion; and made me, whose talents were unequal to higher things, humbly contented with the profession of physic. The present work therefore is with justice address'd to you, who had so considerable a share in the accomplishing of it. Accept it with the same disposition wherewith it is offer'd; and let it stand as a public monument of fraternal affection.

I have frequently thought my self happy in having a brother of such sanctity and manners, as render'd him worthy to be a teacher of the tidings of salvation; and this both by doctrine and example; without vainly affecting any thing further. If I, too, have acted my part in a manner which may give you any pleasure in the reflection, I shall be doubly satisfied. Adieu, Brother, and while you run over the ensuing pages, remember what pleasures we have formerly reaped in these pursuits.

The



The AUTHOR to the
R E A D E R.

I Little imagin'd that ever I should publish any thing in chemistry: there are already so many books extant on it, and several of them so well written, that I scarce saw room for me, either to do better, or to produce any thing new upon the subject. The duty of my professorship, indeed, required me to give annual lectures in chemistry; but I had no farther aim in this, than to teach the first rudiments, and exhibit a few examples of the art, to those under my care. And to this end, the order wherein I digested matters, and the openness and simplicity wherewith I delivered them, might perhaps be of service. In both these respects, indeed, my endeavours still seem'd wanting to raise chemistry, at length, into a rank with the other academical sciences*. This view I sedulously pursued, accordingly; and having done thus much, thought my self abundantly acquitted; and judged that nothing farther would be expected of me. But things have taken a different turn: and the ingratitude of some of my hearers, whose interest I was ever studious to promote, together with the insatiate avarice of certain booksellers, who aim at lucre by the most scandalous means; have render'd my professorship of chemistry disagreeable to me. In conjunction, these people, under a false pretence of the interest of learning, have taken an unwarrantable liberty both with me, and the public; and been audacious enough to publish *Institutiones & Experimenta Chemicæ* † under my name, without my participation. I will not rehearse the many false, ridiculous, and absurd things there attributed to me in every page: a detail too nauseous to entertain the reader with. Yet such is the infelicity of the age, that lest future ones should want some proof of its depraved taste,

* Hence may appear the reason of our title: *A new Method of Chemistry*; for the author's aim is not to improve the matter, but only the manner of the science: that is, to dispose the materials of it in a more natural and more useful order, than had ever been done before.

† The title of the surreptitious edition.

the book thus vilely publish'd, found plenty of purchasers; to the great injury and reproach of those who were weak enough to buy and commend it. Hence I frequently lay under a necessity of seeing the detested piece, even in the hands of my auditors; who, to my face, were daily comparing my words, as I delivered them, with the text thereof. Tired out with the insult, I sued for relief from the Magistrates; and had obtained it, but that some, from whom I had deserved better, and who had promised me very different usage, were pleased to create delays, and even throw obstacles in my way. A lamentable instance how fond some persons are of every opportunity of affronting Men of Letters! On these, and other motives, I relinquish'd my professorship of chemistry; which I had no sooner done, than I found new fatigues prepared for me: my friends began to represent to me the necessity I was under, of publishing my *Chemical Institutions* myself; to shew the method wherein I had taught the art, both in my public lectures and private. I objected to them, that the private course, being only calculated to acquaint beginners with the first elements of the history and method of chemistry, was unfit for the public; and likely to prove even disgustful to those who are already proficient. They still insisted, that the spurious edition had met with success; was every where applauded, much call'd for, and sold dear; and, unless I prevented it, would quickly come to a new impression. This brought *Petrarch* to my mind, who bewails the unhappiness of his age, upon finding himself ranked among the chief poets of it. With what confidence could I, conscious of my own insufficiency, and full of admiration of other authors, enter the list of writers in chemistry? At length, however, I undertook the disgustful work, which I now publish; and which I openly declare was extorted from me.

Thro' the whole, my view has been to express myself in the fewest, as well as the clearest words possible; to which end I have studiously avoided the use of technical terms peculiar to the art. That this is practicable, appears from the immortal works of the incomparable *Agricola de Re metallica, de Possilibus, & Subterraneis*. I wish, that in compiling mine, I had been indulged sufficient time, to have imitated so excellent an author! But, considering the manifold distractions I laboured under, and the irksomeness of so long a work, 'tis no wonder if words not purely *Roman*, have crept in. Sometimes also, I may seem to pursue little matters too minutely; but this I did with design to inculcate caution upon the reader; and teach him to avoid the dangers which are here impending on all hands. I had my novices still before my eyes; and was therefore obliged to point out all the roads of danger and mischief. For the like reason, I usually keep to single

The AUTHOR'S PREFACE.

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experiments, and do not hastily lay down general rules; that youth may hence learn to enter the laborious, but true path, which leads to the knowledge of physical truth.

It being necessary to incorporate into the first part, several chemical lectures which I had delivered in public, at different times, and to confirm them with new observations; I have here been sometimes betrayed into a repetition of what had been said before: and by such means, with my own too numerous occupations, the book has swell'd to its present bulk. How often, in the course of the composition, have I envy'd those happy writers who have leisure to measure, digest, and polish their writings; while I am forced to pen my thoughts hastily, amidst a thousand avocations, and often necessitated to leave things in a condition very different from what I would have done, could I have enjoy'd my wish'd retreat; especially having it in view to pursue and corroborate some points by new Experiments*.

As for the experiments contain'd in this book, they have been shewn in public some years ago: which I mention lest any one should suspect them surreptitiously taken from other authors.

Be pleas'd, reader, to accept what I here offer; pardon my thus loading thee; impute my confidence in publishing to the earnestness wherewith the first book was received; and be assur'd, that the following Catalogue, which I do not give without blushing, contains all the books published by me.

Oratio de commendando studio Hippocratico, delivered and printed at Leyden in 1701. for Abr. Elsevier.

— *de Usu Ratiocinii Mechanici in Medicina*, 1703. for John Verbeffel.

— *quã repurgatæ Medicinæ facilis asseritur simplicitas*, 1709. for John vander Linden.

— *de comparando Certo in Physicis*, 1715. for Peter vander Aa.

— *de Chemia suos Errores expurgante*, 1718. for Peter vander Aa.

— *de Vita & Obitu clarissimi Bernardi Albini*, 1721. for Peter vander Aa.

— *quam habui, quum, honesta missione impetrata, Botanicam & Chemicam Professionem publice ponerem*, 1729. for Jf. Severinus.

— *de Honore Medici, Servitute*, 1731. for Jf. Severinus.

* As the author appears to have wrote this preface, and the Book itself, under a good deal of distraction; it is no wonder that

he has been frequently betrayed into omissions, oversights, and errors; which we shall endeavour in some degree to avoid.

Institutiones

The AUTHOR'S PREFACE.

Institutiones Medicæ, in usum annuæ Exercitationis domesticæ, 1708. for John vander Linden, P. & F. since re-printed several times, with additions, 8º.

Aphorismi de cognoscendis & curandis Morbis in usum Doctrinæ Domesticæ, 1709. for J. vander Linden; since re-printed several times, with additions, 8º.

Index Plantarum quæ in Horto Academico Lugduno-Batavo reperiuntur, 1710. for Cornelius Boutestein, 8º.

Libellus de Materia Medica, & Remediorum Formulæ, 1719. for Jf. Severinus, 8º. and since again in 8º.

Index alter Plantarum, quæ in Horto Academico Lugduno-Batavo reperiuntur, 1720. for Peter vander Aa.

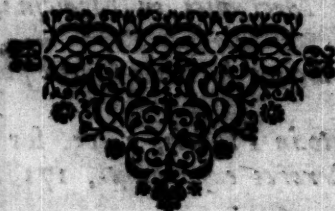
Atrocis, nec descripti prius, Morbi Historia, secundum Medicæ Artis Leges conscripta, 1724. for Boutestein, 8º.

Atrocis, rarissimique Morbi Historia altera, 1728. for Samuel Luchtmans, and Theodore Haak, 8º.

Tractatus Medicus de Lue Aphrodisiaca, præfixus Aphrodisiaco, 1728. for John Arn Langerak, and John and Herman Verbeck, fol.

Epistola pro Sententia Malpighiana, de Glandulis, ad Clariss. Luischium, 4º. for Vander Aa.

All other Pieces published under my name, excepting a few Prefaces, are spurious.



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THE

THE DESIGN OF THE WORK.

1. **M**Y Design is to initiate students in the knowledge of chemistry: and to do this in the most effectual manner, I shall give a clear methodical explication of all that is necessary for understanding the best authors, and for performing the chief operations, in this experimental art; that both head and hand may come qualified for the effectual treatment of it (*a*). *Design.*

2. This, it must be own'd, is no easy thing to do, in a science like chemistry; which has been cultivated rather by experiments at random, than upon any regular principles; and by persons usually destitute of all assistance of learning, or knowledge in the liberal arts. The materials they have left us are only a confused heap of events and incidents, hastily put down, just as the things themselves happened to turn up: in which also many particulars are either suppressed, or very remissly related, merely because familiarly known to themselves, though otherwise of the utmost importance, especially to beginners, in order to their conceiving the true principles on which other things depend. And what still further inhances the difficulty, the professors of this art, unqualified as they were, have often taken upon them to reason and dispute, advance general rules, and enter into the causes of phenomena (*b*). *Difficulty of it.*

3. Yet all these obstacles may be surmounted, by making a collection of the several effects, which the art has actually produced; justly deducing general rules therefrom; and duly digesting the whole: especially if this be undertaken by a person, who has not only been much conversant in the art itself; but has cultivated his genius by due exercise and application. In which respects I may be allowed to own myself, not *Practicability of it.*

(*a*) The manner of the author in addressing himself to his pupils, as if they were constantly before him, is here changed for the common method of writing, which we apprehend will be found more agreeable.

(*b*) A very large part of chemistry still lies in the same disorder; as we find in the various writings of those called the adepts, and

Balto- the numerous chemical works of Glauber, Becher, Kunkel, Boyle, &c. which might be digested, verified, and reduced to rule, for enlarging the science. And the doing of this we judge would not only contribute to the improvement of chemistry; but of several other branches of natural philosophy, and many of the arts. 3

Design of the Work.

Division of it. altogether unqualified: whence it is with the more assurance that I enter upon the present course; which will be distributed into *three* parts (c).

Historical part. 4. The *first* will rehearse the origin, progress, cultivation, and fortune of chemistry; recite the primitive authors, according to the order of time; briefly indicate their agreement, or disagreement, on certain points; with the sects that arose from them, and the advantages, or disadvantages, which hence accrued to the art; still assigning to each the share of merit and glory that is his due; and candidly bestowing applause on such as have been most useful. And from hence may they, who have occasion to pursue this science, be furnished with useful notices, to guide their steps. My rule in compiling this part shall be the law commonly prescribed to historians, which enjoins the most rigid fidelity (d).

Theoretical part. 5. The *second* part will deliver certain theorems, or principles of chemistry; wherein all the physical truths, which have hitherto been discovered by chemists, are accurately comprized. These are of a general nature, and will serve to explain certain previous operations, by means whereof, all those in the art of chemistry are to be effected. For we allow of no other *theory* in chemistry, except what is built on general laws; which must originally have been deduced from a multitude of common incontestable facts, always happening in the same manner, so as to authorize the enacting them into a general rule (e). Nor is it allowable to extend even such rule, however true it may prove; but only

Limits of it.

to

General Design.

(c) In our former edition, the author lays down his design thus. "What we are now entering upon is a *body of Chemistry*, delivered in clear terms, founded on sure principles, and raised with undeniable experiments: in the course whereof, will abundantly appear the vast extent and importance of the art; and the share it has, not only in medicine, but in all the parts of natural philosophy, and the mechanic arts. To accomplish this the more distinctly and fully we divide the whole into three parts, *historical, theoretical, and practical.*"

The History of the Art.

(d) It appears from hence, that the author had formed a noble design of giving a most curious and useful history of the art: we earnestly wish he had taken time to finish it! The design of it is concisely laid down in our former edition thus. "We shall shew, from the most ancient and authentic remains of history, (1.) What the art originally was. (2.) In what country, at what time, and by what persons invented, cultivated, and im-

proved. (3.) How it degenerated, and was corrupted. (4.) How, and by what hands it was again urged and restored: and, (5.) How, through various ages, nations, and authors, it is at length transmitted to us".

(e) It is pity the author had not formed a direct theory of chemistry by this rule: we fear the large part of the work, called by the name of theory, will be found a somewhat different thing, from what appears to be here design'd. Instead of a theory of chemistry: in his own sense of the word, he seems to have given a large portion of natural and experimental philosophy, relating to the art; with some general theorems interspersed. What seems to approach the nearest of any part to the theory here proposed, is the *chapter of menstrua*; which contains many general truths, derived respectively from a number of chemical experiments, all confirming the same thing. But as for a just theory of chemistry, it seems to be hitherto wanting; at least in that extent and fulness, which even our present fund of experiments would allow of. See below §. 7.

to apply it to single cases, where the same common reason is found to obtain. For certain bodies have peculiar powers, from whence effects arise, that do not come within the compass of any general theorem; but depend on a certain constitution, peculiar perhaps to some one body (*f*). In forming such theory, a direct use may indeed be made of the demonstrations in physics, as particularly in mechanics, hydrostatics, and hydraulics; since the properties common to all bodies, and what further affection certainly flow therefrom, have their place in chemistry. But one cannot be too reserved in this use; by reason that those singular properties found in some bodies, will, if applied to others, falsify the mathematical demonstrations, which might hold true every where else. Thus *Galilæo* has fully demonstrated the law, wherein a heavy body let fall, from on high, descends in a spiral, or elliptical line, with a certain degree of acceleration, to a point of the earth, perpendicular to the horizon of the point from whence it was at first let fall. But if a load-stone be thus let fall; and, in the course of its descent, enter the sphere of activity of another load-stone, the demonstration will not hold. So what *Archimedes* has shewn, concerning bodies equipondérant in water, holds infallibly true, if considered only in common cases; but prove false in the instance of gold; which, though it sink in other fluids, is suspended and dissolved in light *aqua regia*. Due regard being had to this rule, the discoveries of naturalists and mathematicians will always be advantageous, never injurious to the art of chemistry (*g*).

Use of physics
and mathematics
in chemistry.

6.

The Theory.

(*f*) For the sake of Illustration, we shall give the nature and design of a theory of chemistry from our former edition. "Under the theory of chemistry we lay down all the general truths, which the particular experiments of chemists have hitherto demonstrated. These are what we shall here assume, or take for granted; and the whole body of such universal truths, makes what we call the theory of chemistry. For chemistry is no science formed *à priori*; 'tis no production of the human mind, or raised by reasoning; but collected *à posteriori*, from experiments. It took its rise from various operations; casually made, and observing those that had one and the same uniform tendency, without any expectation of what followed; and was only reduced into an art by collecting and comparing the effects of such uncertain experiments, and noting the tendency thereof. So far then, as a number of experiments agree to establish any unquestionable truth; so far they may be considered as

"constituting the theory of chemistry. Now, such a theory is necessary to be premised to every art and something equivalent hereto is practised by every artizan, in teaching his disciple how to proceed orderly in the exercise of his art. And accordingly it would be impossible to teach the practice of chemistry to advantage, without some such previous theory. Thus it would be to little purpose to give a novice a parcel of rosemary, for instance, and bid him, without any addition, distil a water from it, that should contain the natural aromatic taste and odour of the plant; unless he knew before hand this general truth, "That plants exposed to a gentle heat, like that of the summer's sun, causes them to exhale their more subtle volatile part;" which part being collected and condensed, by means of proper vessels, appears in the form of water, and is the thing that is here required."

(*g*) Too much knowledge from all the sciences cannot be derived into any one, in order to enlarge and perfect that one; and thus chemistry,

Design of the Work.

Practical part.

Method of digesting the processes.

Use of the theory.

6. The *third* part will exhibit the actual operations of chemistry; whereby bodies are changed, agreeably to the rules of the art, and to the end proposed therein. Here I shall endeavour so to dispose things, as that none of the usual processes, at least of those worth the knowing, (b) may be omitted; and that those be always placed first, which are necessary for the performance of any subsequent ones (i).

7. In this part, all the theorems laid down in the proceeding part will become useful, and contribute to the easier understanding of the operations: so that between the two, the student will be sufficiently instructed,

chemistry, which is a branch, or peculiar part of experimental philosophy, requires all the assistance, that can any way be procured, to improve it. But then, great care must be taken, lest what was intended as a help, should prove a hindrance; as hath frequently happen'd, when men reason rashly from one science to another. And thus, in some respects, physics has hurt chemistry, and chemistry injured physics, through the unskilfulness of such as knew not how to reason right. Students therefore should be carefully instructed in the *art of reasoning justly*; for the turbulent reasoning of uncultivated minds, is a dangerous thing to science, and productive of errors and mischief.

(b) There may perhaps be abundance worth the knowing, that do not occur in this performance. See particularly the writers on metallurgy, and *Boyl, Becher, Stahl, &c.*

The Practice.

(i) " *Thirdly*, we shall exhibit a course of chemical operation producible in bodies, by attending to the laws, or axioms of the art. This part we have been long conversant in; and from the first, found it necessary to go in a *new method*, greatly differing from what has been observed by the most celebrated chemists of *Europe* in their courses, and lectures. All these authors, we have been at the pains of reading over; and have every where found them as abrupt and disorderly, as they are scanty and defective; a tumultuary mass of pharmaceutical processes, without any certain design or coherence, is all they afford. The processes of chemistry, are, indeed, almost infinite; and it were impossible to exhibit all that the chemists have hitherto invented, in the *course* of a man's life.

" 2. The method we pursue then, is to reduce all the most useful and instructive ones to certain classes; to begin with the most simple and easy of these; and lay them down in such a manner, as to serve for a basis to the next; and those, in their turn, to others; till we arrive at the most difficult,

" cult, and complicated processes, by an easy and gradual ascent: the second operation, being never required to the understanding of the first; nor the third to the second; but the first always necessary to the second, and that again to the third: so that there will be no occasion for ever repeating the same operation. Two hundred processes, conducted after this manner, will set all the fundamentals of the art to view; and a few canons, or general rules, subjoin'd to each process, will open the way for all the other numberless processes to be performed: so that whilst the reader has only the marrow of the art presented him, he is really put in possession of the whole bulk thereof.

" In each process our method shall be, (1.) To exhibit the subject; (2.) To explain the operation: (3.) To shew its effects on the object: and, (4.) To deliver the genuine virtues and medicinal properties of each production, as we have approved them by abundant experience. And these we hope to describe in the most severe and scrupulous manner; far from any taint of the wild flights, and extravagancies usual among the chemists.

" 4. 'Tis certain, medicine has suffered extremely from this quarter; every chemist affixing virtues to his preparations at random. Thus salts obtain'd from the ashes of plants, having, on some occasions, been found of service in tertians and quartans; immediately a febrifuge virtue is assign'd thereto; and they must needs be administered in all fevers indifferently; when perhaps in inflammatory fevers, they promote the disease. Indeed, the chemists should always be suspected, when they boast of general virtues in their preparations: there is nothing so precarious, and ill warranted as such pretences; nor can a man soberly say, there is any such thing as one preparation always effectual in any disease; no universal febrifuge, for instance, against all fevers; nor we fear any general lithontriptic, in all cases of the stone".

structed, both in speculation and practice, for the actual performance of what belongs to this art. At the same time, each operation is considered as an example of one of the single cases, from which the general theorem was first deduced (*k*). By which method the perfection of chemistry may be arrived at, without incumbering ourselves, more than needs, in a pursuit, which of itself is sufficiently tiresome. For want of this, the endless labours and processes of chemists are of little moment (*l*), and only serve to keep them in a continual chace, without furthering them a jot; whence instead of a reward at last, they are often left considerable losers (*m*).

(*k*) Here we have a clearer intimation of what the author means by a *theory of chemistry*, in the sense above delivered*: for since every process in the practical part of this work, is to be a single instance, agreeing with all the rest that can be found of the same kind; a general conclusion, or theorem, may be safely drawn from this single instance; as the process itself will be at the same time as well general as particular. But then care will be required on the side of the author, (1.) To select always such an instance as may suit several particulars; and afford a just and tolerably general conclusion, including neither too little nor too much: (2.) To draw no inferences from it, but what are warranted by the experiment; and cannot be falsified by any other instance, or observation; and, (3.) The reader also must be here as careful not to draw a too general conclusion, or extend the instance to particulars, which it may not suit. And if these cautions are well observed a just theory of chemistry might thus indeed be formed, by drawing general conclusions, from a sufficient number of well verified instances; or from a single instance so far as it is general. Thus, for example, as the author's first process, performed upon rosemary, shews that a water, containing the smell and taste of the plant, may be obtained from it by dry distillation, with a gentle heat; and it being known by various other trials, that, in

like manner, a water may be drawn from many other plants, containing their respective scents and tastes; it follows, that this experiment is general, or holds of all plants, agreeing in the respect of affording such a water by such treatment; but must not be extended to all vegetable: for in many of them the process does not hold true, as in *carduus*, *sorrel*, *gentian*, *apples*, &c †. However, this single experiment is, in some tolerable degree, general. And hear the author's conduct deserves to be admired and imitated; as being no less useful than beautiful: for it greatly eases the labour both of the teacher, and the learner; shortens the way to science; makes particulars generals; and at once exhibits both the theory and practice of the art.

(*l*) Till they come to be digested, verified, brought to order, and applied; by the art of just reasoning.

(*m*) This method might well deserve to be tried in other sciences, that will allow thereof; as in physic, for example, where we have numerous histories of particular cases, and books of single observations, that afford but slender assistance in the knowledge and cure of distempers; whence, after a tedious course of reading, the student may come but ill prepared to practice, and be obliged to find out rules and theorems for himself; without being much the wiser for the scatter'd experience of others.

* See above §. 5.

† See process I, II, &c. upon vegetables.

(1) The Commission has been informed that the Government of India has decided to grant a concession of 10% in the price of the goods to be supplied to the Government of India. This concession is to be granted to the Government of India for the purpose of enabling it to meet its financial obligations.

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5. carrying out of the policy of
6. non-interference in the internal
7. affairs of other countries. This
8. has been due to the fact that the
9. United Kingdom has been unable to
10. secure the cooperation of the United
11. States in the carrying out of the
12. policy of non-interference in the
13. internal affairs of other countries.

[illegible]

1. The first of these is the fact that the
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1. The first step is to identify the problem or question that needs to be answered. This involves understanding the context and the specific requirements of the task.

THE HISTORY OF CHEMISTRY.

1. **T**HE name chemistry, written in Greek *χημία*, or *χημία*, *chemia*, or *chemia* (a), is so ancient, as perhaps to have been used in the antediluvian age (b). Of this opinion was *Zosimus*, the *Panapolite* (c), whose Greek writings, though known so long as before the year 1550 to *George Agricola*, and afterwards perused by *Jos. Scaliger* and *Olaus Borrichius*, still remain unpublished in the King of France's library (d). In one of these, entitled, "The instruction of *Zosimus*, the *Panapolite*"

Origin of the
name che-
mistry.

(a) Allowing this to be the true orthography of the word, yet it might be pronounced in Greek, as if it was wrote *chimia*, *chimistry*; because both the letter *χ*, and the diphthong *η*, are sounded as *i* by the modern Greeks, and perhaps were so by the ancient*. But the word is variously written, as well as variously derived†.

(b) Men generally betray a fondness in fixing, as high as possible, the origin of the arts they favour; but we can see no just reason for straining the truth, or taking up with dark and doubtful evidence, upon these occasions: it being not so material to make an art appear ancient, as to make it useful, in order to procure it esteem. The learned *Olaus Borrichius*, whom our author chiefly follows, has taken pains to trace the origin, progress, and

fate of chemistry; but appears sanguine in the pursuit. He finds much chemistry in the sacred writings, and the ancient poets; takes spurious authors for genuine; and lays sometimes a stress upon weak, or suspected authorities; thus acting the part of a pleader, rather than that of a rigid enquirer‡.

(c) He seems to have lived about the beginning of the fifth century; and wrote, as is supposed, several treatises, which are preserved in the King's library at Paris: but as they remain unpublished, we can form no solid judgment of them; only, if one might venture a conjecture, from the specimen and account which *Borrichius* gives of them, they seem to be mystical and enthusiastic§.

(d) Proofs drawn from the titles and fragments of ancient manuscripts are extremely fallacious,

* See *Westein* upon the pronunciation of the Greek language.

† See *Petr. Lambet. lib. 6. Comment. de Bibl. Cesar. p. 174. & Du Cange Glossar. tom. II. p. 1771. in voce χημία.*

‡ See his pieces *De Ortu & Progressu Chemiae; & de Hermetis, Aegyptiorum & Chemicorum Sapientia.*

§ See *Borrich. de Hermet. Aegypt. &c. p. 48, 49, 50, &c.*

Fabulous origin
from demons.

"*nalopite* and Philosopher, out of those written to *Theopsebia*, in the eighth book of *Imouth* (e)," he says expressly, that the art called *chemia*, was first taught by demons to the daughters of men, in consideration of certain favours. The passage is transcribed at large by *Jos. Scaliger*, in his notes on *Eusebius* (f), and *Olaus Borricbius* against *Conringius* (g); it runs thus (b): "The sacred books, or writings, say there are a kind of demons who en-joy women. *Hermes* (i) in his physics testifies as much; and all our learning, both open and occult, confirms the account. What the ancient divine writings relate, is, that the angels, inflamed with the desire of women, instructed them in all the works and mysteries of nature (k). Now our first most ancient tradition, called *χημία*, is on these very arts: the book they were contained in was called by the same name; and hence the art itself was called *χημία*, *chemia* (l).

fallacious, and good critics never depend upon them; because the ancient copists made a trade of their art, and sold spurious copies under counterfeit titles, and the forged names of eminent authors; whence those numerous pieces of the supposed *Hermes Trismegistus*, &c.⁴ This is the rather mention'd here, that it may be kept in mind, as we proceed in the history of chemistry; where we shall often be concern'd with ancient manuscripts, unpublished writings, and suspected authors.

(e) *Χημία Ζωόχημος*, &c. *Imouth* is a supposed name for chemistry; see below § 5, and 10, 16. and the writer is supposed, by the learned *Conringius*, to be the most ancient one at present remaining upon chemistry. See the catalogue of Greek writers, below §. 16.

(f) *Euseb. Chron.* p. 243, 258.

(g) *Ol. Borrich. de Ort. Chem.* p. 12. & *contra Conringium.* p. 49.

(b) We judge it proper to omit the Greek quotations, which disturb the text of the author in this history of chemistry; and instead thereof to give an English translation of them. Those who please may consult the originals, to which the references will be made.

(i) Who this *Hermes* was, seems not easy to discover: none of his genuine writings having come down to us; and there having been several persons of the same name, and several books published under it; though all of them that are extant appear to be spurious. *Borricbius* labours to prove, against *Conringius*, that the first *Hermes* was an ancient Egyptian, an excellent physician and chemist,

a great writer, and a general benefactor to mankind †. It appears pretty plain, that the Egyptians, and after them several other nations, supposed *Hermes* to be the inventor of all the arts and sciences ‡; that he wrote of some; and that, having a prodigious reputation, many others were father'd upon him ||.

(k) The Greek passage, as it stands in *Borricbius*, is fuller than in the author; and adds here, that, "hence those angels were excluded heaven; the knowledge they thus imparted, being all evil and unprofitable**."

(l) *Clemens Alexandrinus* relates part of the same fable, but without mentioning chemistry; "How the angels, whose lot was assign'd them in heaven, falling into effeminacy, revealed to women what secrets they knew; whilst others concealed, or rather reserved them for the coming of the Lord, &c. ††."

Fabulous Origin of the Art.

"1. The doctrine of demons here mention'd by *Zosimus*, is also delivered by *Plato*, *Philo-Judeus*, and other philosophers; who represent them as endowed with a penetrating mind, and boundless knowledge; not confined to our ways of conceiving things relatively, but fitted to perceive them as they are in themselves; not incumbered with a solid body, like us; but a penetrable one like air. *Zosimus*, who adopts the doctrine with a peculiar fondness, observes further, that, beside the intuitive knowledge of the demons, there was even in the antediluvian world, a kind of human sciences acquired

* See *LeClerc. Hist. de la Medecine*, p. 12, 13.

† See *Borr. Hermet. Egypt. & Chemic. Sapient. in initio, & alibi passim.*

‡ See *Diodor. Sic. L. 1. Cas. de Bello Gall. L. 6. Jamblicus de Myster. Egyptior. Clem. Alex. Strom. L. 6.*

|| See *Morhof. Polyhist. C. II. L. 1. & Le Clerc. Hist. de la Med. p. 12, 13.*

** See *Borrich. de Ort. & Progress. Chem.* p. 12.

†† See *Clem. Alexander. Strom. §.* See also below, the note on §. 2.

2. This ancient fiction took its rise from a mistaken interpretation of the words of *Moses* (m), "That the sons of God saw the daughters of men, that they were fair; and they took them wives of all which they chose (n)." From whence it was inferred, that the sons of God were *dæmons*, consisting of a soul, and a visible, but impalpable body, like the image in a looking-glass; (to which notion we find several allusions in the evangelists (o); that they know all things, appear'd to men, conversed with them, fell in love with women, had intrigues with them, and revealed secrets (p). From the same fable probably arose that of the *Sibyl* (q), who is said to have obtain'd of *Apollo* the gift

"acquir'd only by reason and experiments; adding, that they in whom the latter knowledge was alone found, were denominated the sons of men; and the former the sons of God. The same notion of *dæmons* prevails among many to this day; under the name of apparitions, or spirits, who roam about with their penetrable matter, capable of discovering themselves to men; and even of possessing them after the same manner as the sole does the body. Many instances of the like belief might be given from the ancient Jews, and the earliest Christians; to say nothing of the current opinion of the *Mahometans*, *Arabs*, and other *Asiatics* and *Africans*. These *dæmons* too of the ancients were supposed subject to human passions; they saw the daughters of men, loved them, and courted them in marriage; and, as an equivalent for their virginity, offer'd them a book containing the whole body of their science. The dowry was accepted, and called *divine tradition*; and this mysterious knowledge *chemia*: sometimes *revelation*; and by *Zosimus* the sacred art. *Philo Judæus* is full of these reveries; and from him *Zosimus* might borrow half the incidents of the fable.

2. This *chemia*, or *chemia*, *Zosimus* will have the same with the ancient *cabala* of the *Jews*; which perish'd with all their antiquities, in the destruction of *Jerusalem*, excepting some fragments retriev'd from the common ruin, and published in the *Talmud*. These fragments are but few, and besides, intermix'd with much trumpery. But *Zosimus* residing in the Emperor's court, had an opportunity of perusing many of the ancient monuments then extant in those libraries, which have since been plunder'd by the *Saracens*; so that his account carries with it the greater authority.

3. From the whole it may be argued, that as *Zosimus* deduces the name, and the

art *chemia*, from the angles, and supposes both communicated by them to their mistresses; both must be earlier than the flood: since the like intrigues related by *Moses*, are expressly refer'd to the antediluvian ages."

(m) *Borrichius* thinks it probable that this piece of gallantry is taken from the apocryphal fragments of *Enoch*, with some interpolations; because the personated *Enoch* in *Synellus*, cited by *Scaliger*, in his *Opus Eusebianum*, relates that "these angels taught men to prepare poisons and charms;" and because *Tertullian*, in his book *de Cultu Fami-*
narum, c. 10. says that "the wicked angels condemn'd of God, first discover'd those alluring things, gold, silver, the art of dyeing, painting the eye brows, &c. as *Enoch* relates."

(n) *Gen. vi. 2.*

(o) "But they were terrified and affrighted, and supposed that they had seen a spirit." "Behold my hand and my feet, that it is I myself: handle me and see, for a spirit hath not flesh and bones, as ye see me have." Again: "And when the Disciples saw him walking on the sea, they were troubled, saying it is a spirit; and they cried out for fear."

(p) *Borrichius* apprehends those here called the sons of God, were the sons of *Seth* and *Tubal Cain*; and that being instructed by their parents in the mysteries of nature, but falling afterwards into unlawful love with the lewd daughters of *Cain*, they profan'd these secrets by an imprudent communication of them: for he thinks it not suitable to the nature of real angles, to have any such commerce with women, as that here mention'd.

(q) The fable says, that *Phæbus* fell in love with a beautiful nymph called *Sibylla*; but meeting with some repulse, he offer'd to comply

* See *Borrich. de Ortu Chem.* p. 13.

† See *Borrich. de Ortu Chem.* p. 14.

† *Luk. xxiv. 37, 39.*

† *Matt. xiv. 26.*

Real antiquity of the name chemia.

gift of prophecy, and revealing the will of heaven, in return for a like favour. So prone is the roving mind of man to figments, which it can at first idly amuse itself with, and at length fall down and worship (r).

3. On the other hand, in ancient times the country of Egypt was called by the name *Chemia*, as appears from this passage in *Plutarch* (s): "Besides, they call *Egypt*; which has an exceeding black soil, by the same name as the black of the eye, viz. *Chemia* (t)." It was also denominated *Hermochemios* (u); as we are assur'd by *Steph. Byzantinus* (x). From the whole we may conclude that the name first obtain'd before the flood (y); continued in use in succeeding times; and then denoted, (1.) The knowledge of the

works

ply with her own conditions; when she demanded, as the price of her favour, extreme long life, and the *δῖος βουλὴ*, divine arcanum, or heavenly wisdom; from whence it is supposed the name *Sibylla* was derived. This fable has some correspondence with that of *Zosimus*; for here the son of a god falls in love with a virgin, and reveals celestial secrets to her.

(r) This prudent reflection of the author upon the scrap of fabulous history above produced, which himself calls but a fiction, makes us the more wonder that he should draw a serious conclusion from it, as he does in the next paragraph, in order to render it probable that the name *chemistry* is of antediluvian date. Some have imagin'd that the history of this art was partly borrow'd from the Jewish idolatry: the rabbinical writings being full of the commerce between angels and women; but the effects thereof are represented as very fatal on both sides. The unhappy passion occasion'd angels to be expell'd heaven, and, according to these writers, man to be expell'd paradise.

(s) In *Isti & Osiris*, p. 364. C.

(t) By which *Plutarch* may seem to intimate that the word *chemia*, in the Egyptian language, signified black or sooty.

(u) This should seem to intimate, as if the Egyptian *Hermes* was the inventor or improver of chemistry; a point copiously prosecuted by *Borricius* †.

Etymology.

"Instead of black, some will have the word originally denote *secrets*, or *occult*, and derive it from the Hebrew *chaman*, or *baman*, a mystery; whose radix is *cham*. And accordingly *Plutarch* observes, that *Egypt*, in the same sacred dialect, is sometimes wrote in Greek *Χαμία*, *Chamia*: whence the word is easily deduced from *Cham*, eldest son of *Noah*, by whom *Egypt* was first peopled af-

ter the deluge, and from whom in the scripture-style, it is called the *Land of Cham*, or *Chem* †. Now, that *chaman*, or *baman*, properly signifies *secrets*, appears from the same *Plutarch*, who mentioning an ancient author, named *Manetho Sebennita*, who had asserted, that *Ammon* and *Hammon* were used to denote the God of *Egypt*; *Plutarch* takes this occasion to observe, that in the Egyptian language any thing secret or occult, was called by the same name *Hammon*. Add, that *Hecataeus Abderita* notes *Ammon* to have been a common term of invocation, whereby the Egyptians called one another when out of the way, or not to be found; and hints, that it had no peculiar relation to their great god, which was the universe, otherwise than as he was secret and invisible, and was hereby called to manifest himself. Lastly, the learned *Bochart*, keeping to the same sense of the word, chuses to derive it from the Arabic *chemia*, or *kema*, to hide; adding, that there is an Arabic book of secrets, called by the same name *kemi*. What we gather from the whole, is, that our art, chemistry, should appear to have been originally thus denominated, because not fit to be divulged to the populace; but treasured up as a religious secret."

A reader, who can take delight in ancient obscure fables, and modern learned glosses thereon, might find scope enough in the present enquiry; but instead of entering farth'r into the subject at present, we should rather refer to *Borricius*, *Conringius de Hermet. Medicin.* *Tallius de Vitulo Aureo*, *Hornius de Arcu Noe*, *Kircher. Oedip. Egypt. Voss. de Antiq. Med.* & *Obs. Var. c. 14.* *Dickenson. Physic. Vet.* *D'Herbelot. Bibliothec. Orient. in voc. Kimia & Simia.* *Pocock Spec. Hist. Arab. Litt. edif. & curi passim.*

(x) See below, §. 10.

(y) See the note above (r).

* See the note upon §. 4. below.

† *Psal. cv. v. 23.*

† See his *Piece de Hermet. Egypt. &c. Sapien.*

The History of CHEMISTRY.

III

works of nature. (a.) A book containing the discovery of such an art. And, (3.) That *Hermes* in his physics made mention of it (z).

4. Further, the word if written *χημα*, *chemia*, imports in *Arabic* to *bide* (a); and if *chemia*, any black object, for instance the black of the eye, as is intimated by *Plutarch* (b). There appears a nearer affinity between the two acceptations; at least among the writers in hieroglyphics, with whom the black of the Eye imports something hidden and precious: and the more if we consider that the same *Egypt* is called in scripture, "the land of *Cham* (c);" and that the *Egyptians* in their language called God *Amun*, *Ammon*, which according to the testimony of *Manetho Sabennita*, signified something occult, or hidden (d). It may be added, that to this day, the same country is called by the *Copts*, *Cemi*, as has been also observed by *Bochart* (e).

Literal signification of it.

5. The word therefore appears to import as much as hidden, mysterious, or secret; and is either written *chemi*, *chemia*, *alchemia*, *alkumia*, *chemia*, *imouth*, or *poëtice* (f); sometimes it is called the *spagyric*, and sometimes

Synonyma's of it.

C 2

(*) No greater stress should be laid upon the conclusion than the premises will support. In matters so remote, so mix'd with fable, and so imperfectly handed down, what certainty can be had? and where is the use of deriving either the name or knowledge of chemistry, from the earliest antiquity? In matters of this kind, it is of importance to let students see that even learned men have their weakness; whence they should be upon their guard against credulity and precarious evidence. The author, in our former edition, says, "That after *Zosimus*, *chemia* became a common term among the *Greek* writers, in the sense 'tis now used. And if we hear nothing of it among the *Romans*, 'tis perhaps because that after the translation of the seat of the empire to *Constantinople*, *Greek* becoming the court language, scarce anything was wrote in *Latin*. They were most of them divines who treated of this art, which was conceiv'd to have a more immediate relation to religion. And hence it is scarce ever mention'd but in terms that imply such relation; viz. of the sacred art: of the *Egyptian* art. But in the seventh century, when *Europe* was over-run with the *Barbarians* from the north, *Latin* and *Greek* shar'd the common fate of learning; and not only the art, but the very name of *chemia* was forgot; and thus they remain'd till the thirteenth century; when *Bacon* and *Ripley* retriev'd, and brought them both on the stage again; not as old

"things, but taking them for a new doctrine."

(a) We cannot see the justness of this *Arabic* origin. Is it probable, that *χημα* should be borrow'd from the *Arabs*, when the name was in use among the *Greeks* many ages before the *Arabs* cultivated chemistry, or any other art? Besides, the *Arabic* root which the author assigns is not written with a *ch*, but a single *c*, or *k*, *cama*; and the name of the art in the same language still differently, *khimiya*. It is in effect more probable the *Arabs* borrow'd the name from the *Greeks*, as *Renaudet* imagines*; or perhaps immediately from the *Copts*, who called any thing that was black *chemia*; and particularly gave the name to their country from the blackness of the soil: and the *Arab* writers are so far from challenging the invention of chemistry to themselves, that they frankly ascribe it to the *Egyptian Ammon*†.

(b) *De Il. & Of.* p. 364. C.

(c) *Psal.* cv. v. 23.

(d) *De Il. & Of.* p. 354.

(e) It appears somewhat odd to derive the name chemistry from an *Arabic* word, and yet to suppose that name in use before the flood; as if the *Arabs* were a nation before the dispersion; and their language in use before the building of *Babel*: neither of which the *Arabs* themselves pretend to†.

(f) It seems to be called *poëtice* from its supposed creative power, or making one thing out of another; and this name was particularly

* *Anc. Relat. des Indes*, p. 375.

† See *D'Herbel. Bibl. Orient. Voc. SIMIA*, p. 810.

‡ See *Pocock Præf. ad Carm. Tog. & Spec. Hist. Arab.* p. 38, 40.

times the *byssopic* art (*g*), on account of its separating of its pure from impure.

Technical signification of it.

Name applied to metallurgy.

Inventor of metallurgy.

Difficulty of metallurgy.

6. In effect, among the first authors who used the word, it imported all knowledge of natural things; tho' from this chaste acceptation it was afterwards injuriously preverted to another: a misfortune which has likewise befallen the word *magic*. And as metals constituted a large and distinguish'd part of these natural things, the word by this means came to be applied to metallurgy; an art which appears to have been cultivated in the antediluvian days: for we find that *Tubal-Cain*, who was the *Vulcan* of the ancients (*b*), the son of *Lamech* by *Zillah*, and the eighth from *Adam*. was so skilful in the preparation of brass and iron, as to be able to make utensils thereof.

7. Yet 'tis known that copper-ore requires the utmost labour and art to fit it for use: *Agricola* and *Erker* agree, that it must be melted twelve times before it will become malleable (*i*). The preparation of iron to fit it for human uses, is attended with the like difficulties, and requires proportionable industry and experience; as the same skilful authors have shewn. So that the origin of the metallurgic branch of chemistry, appears as ancient as the word *chemia* itself (*k*).

ticularly applied to the making of gold and silver out of baser materials; and so is the word chemistry itself in some Greek authors *.

(*g*) "*Paracelsus*, a strange coiner of words, appears to have given it the name of *byssopic art*, from that passage in the *psalms*, "Purge me with hyssop, and I shall be clean." "only because chemistry purifies metals; the imperfect ones whereof are called by some of the *Adepts*, leprous or foul." Besides these names of the art †, it also appears to have been called, (1.) The *sacred art*, divine tradition, revelation, heavenly wisdom, or divine *arcana*; from its supposed manner of being communicated: (2.) The *Egyptian* or *Hermetic art*, from its supposed inventor *Hermes Trismegistus*: (3.) And more lately *pyrotechny*, or the art of working by fire; in which sense *Helmont* called himself *philosopher by fire*. Perhaps it might be proper to give this art a new name, (as the old ones seem to have brought some discredit upon it) that should be significative of its nature and use, for as it is a peculiar kind of experimental philosophy, consisting in the treatment of all natural bodies, so as to discover their more internal relations to, or effects upon one another, their productions, powers, and *phenomena*; and this under all possible degrees of simplicity or combination; by means of the instrumental efficacy of fire, air, water, earth, menstruums, &c. it might hence be called *physica individuorum*, or *physica corporum interior*; the physics of concretes, or the internal phi-

8. The philosophy of all the different bodies of our globe. For as mixing mathematics, or mechanics, consider the general, or more obvious properties of matter; such as extension, figure, motion, gravity, elasticity, &c. so this art tends to discover the peculiar, latent, or more internal relations of one body to another; and the operations, or effects of secret internal motions and powers, acting upon the minute parts of bodies; so as to produce separation, mixture, or change.

(*b*) It does not clearly appear that *Tubal-Cain* and the first *Vulcan* were the same person; but is rather contrary to the opinion of some, esteem'd the best writers on chronology. Sir *Is. Newton* makes it probable that *Vulcan* was the same with *Baal-Caan*; and that he lived, not before the deluge, but only about the time of *Dawid*. And the making of *Tubal-Cain*, the eighth from *Adam*, to be the founder of *Egypt*, is, as far as we can see, carrying the antiquities of that country beyond what either sacred or profane history will warrant.

(*i*) Some copper-ore requires to be melted fourteen or fifteen times, before it will become fine, and fit to grain, like hail shot, as at the copper-works at *Bristol*. And it is remarkable, that even the fourteenth or fifteenth *regulus* does not appear very metallic to the eye: tho' another fusion will bring it to copper.

The first Traces of Chemistry.

(*k*) "We proceed in our enquiry to the place

* See *Conring. Hermet. Medic. c. 111. & Reinesf. Var. Leß. 1. 11. c. 5.* See *Du Cange* under the word *Xopala*.

† See above §. 1.

8. The country where this art was first cultivated to advantage, was that wherein the first man inhabited; as we gather from the history of *Tubal-Cain* (1), compar'd with the fables and histories of the ancient *Vulcan*, who appears to have been the same with that Patriarch (m); and is further confirm'd by the origin of the word chemistry, as already explain'd (n). Places where metallurgic chemistry was first cultivated. Asia.

9. From

" place where chemistry had its birth: a subject fam'd for a mighty controversy between the learned *Dane*, *Olaus Borrichius*, and that monster of erudition *Her. Conringius*, which divided the chemists of Europe into two factions. *Conringius* strenuously attack'd the antiquity of the art, which *Borrichius* as learnedly defended; between the two however, several points were admirably discuss'd, which had otherwise never been regarded; so that the public was a gainer by the dispute. Nor must *Vossius* and *Bochart* be forgot, from whom we have receiv'd many curious things on the subject, which shew a wonderful harmony between the *Mosaic* and *Egyptian* annals.

" 2. The *Babylonians* and *Egyptians* were in dispute, for many ages, about the origin of the two nations; each advancing many weighty arguments, in proof of their own superior antiquity. 'Tis hard to determine any thing upon the matter, especially at this distance; but thus much must be allowed, that the god of the *Babylonians* was *Horus*, first king of *Affyria*, and inventor of the art of medicine.

" 3. Now *Horus* signifies fire, and the sun; under the first of which denominations the same deity was worshipped by the *Babylonians*, and under the second by the *Persians*. Whence we have a presumption, that this *Horus* was the same with *Vulcan*, or *Tubal-Cain*; in regard each is held the inventor of fire: besides that *Tubal-Cain* lived in *Mesopotamia*. But this we only advance by way of conjecture. Indeed since that noble treasury of books and manuscripts, founded by *Callisthenes* in *Babylonia*, in the time of *Alexander* the Great, were all destroy'd, we may despair of ever having any further light into the *Babylonish* affairs, from any authentic monuments of history."

(1) " And *Zillah* she also bare *Tubal-Cain*, an instructor of every artificer in brass and iron *."

(m) *Voss. Id. G. I. 65.*

Antiquity of the practice of Chemistry.

(n) " Before we proceed to the antiquity and origin of the practice of chemistry, it may be proper, by the way, to note, in what view we take the art, because the

" different relations or branches thereof, will furnish different *era's*.

" Chemistry, as now conceiv'd, is a system or assemblage of very different parts, which anciently subsisted separate, or at least had a subsistence prior to each other; as the preparing of metals for human uses; the transmutation of baser metals into gold; the preparing of medicines, &c. If now we go to trace the antiquity of chemistry, consider'd as it converts other metals into gold; or, as it prepares an universal remedy for all diseases, the research will not carry us far back: but as it relates to the discovery of metals in the mine, and the digging, separating, and purifying of the same, it challenges the highest antiquity. In this last sense, therefore, it is that we at present purpose to search into the origin and antiquity of chemistry.

2. " The art of metals is, no doubt, of a very early standing. To find, procure, fuse, refine, render malleable, and apply metals to use, is all of antediluvian invention; and was attributed by the ancients to their gods. *Moses*, the eldest author extant, in his genealogy of the patriarchs, relates, that *Tubal-Cain*, the eighth from *Adam*, was the " instructor of every artificer in brass and iron," to prepare the instruments and utensils of life. Now, 'tis apparent nothing of this could be effected without the knowledge of metallurgy.

3. This account of *Moses* is surprizingly seconded by prophane history and fables: *Diodorus Siculus*, who lived in the time of *Cæsar*, when *Egypt* was become a Roman province, had a fair opportunity of searching into the antiquities of the *Egyptians*; and he relates, as the result of his enquiry, a very ancient tradition of one *Hephaestus*, whom that people hold the first inventor of all the arts and operations about metals, and every thing else that undergoes the fire; together with their uses; which art he deliver'd down to posterity, so far as it might be of service to mankind. This *Hephaestus*, of the *Egyptians* and *Greeks* is the same with the *Roman Mulciber*, or *Vulcan*, to whom the same art or invention is ascribed; and the *Vulcan* of the *Latins*, we

* *Genes. iv. 22.*

† *Gen. iv.*

Then Egypt.

9. From the place of its rise it was propagated, like the other arts, into Egypt; where it was vigorously prosecuted. *Moses*, who was skill'd in all the learning of the *Egyptians* (o), was able to burn gold, so as to reduce it to a powder, capable of mixing with water, and fit to be drank (p): which is one of the highest effects of the art, and which the greatest chemists at this day are unacquainted with (q).

10. Again, we find in *Diodorus Siculus*, that *Vulcan* the son of *Jupiter* by *Juno*, and the first King of *Egypt* (r), was deify'd after his death for the discovery of fire; or rather for having taught the application to the making of utensils out of metals; as the same writer expressly notes in these words. "*Vulcan* is said to have been the inventor of the working of iron, copper, gold, silver, and other bodies, capable of being wrought by fire. He further invented all the other uses of fire; and transmitted those arts to artificers and all other men (s)." Accordingly, *Egypt* itself, as we have observed, was in the sacred dialect of that country called *Χημία*, *Chemia* (t) and *Hermochemios* (u); and also *Hephestia*, or *Vulcania* (x): Tho' indeed the great *Scaliger* maintains, that the art of chemistry was by the *Egyptians* called *Imouth*. And in the book entitled *Minerva Mundi*, transcribed from *Stobaeus*, we find *Astlepius* stiled the inventor.

11. Add,

"we suppose was the *Tubal-Cain* of the Hebrews.

"4. Now it appears from *Homer*, *Hesiod*, *Orpheus*, and all the most ancient writers, that *Vulcan* had the art of working brass and iron; and that living under mount *Atna*, he was employ'd in forging arms for the gods and heroes. As *Diodorus Siculus* relates the story, he was the son of *Jupiter* and *Juno*, and the first King of *Egypt*; and that he was afterwards preferr'd to be a god, for having invented fire, and taught men the use of it. The discovery was occasion'd thus, happening to see a tree on fire, kindled by lightning, he approach'd nearer thereto; and perceiving a fence of heat, and that the tree was sensibly consum'd, he cast other wood on the blaze; and thus learnt that wood would maintain fire.

"5. It must be added, that the *Egyptians*, as the same *Diodorus* observes, adored their god *Vulcan*, as the inventor of the whole art and application of metals; so that the accounts of *Moses* and *Diodorus* perfectly coincide, and prove the chemistry of metals almost coeval with mankind."

(o) "And *Moses* was learned in all the wisdom of the *Egyptians*, and was mighty in words and deeds."

(p) "And took the calf which they had

"made, and burnt it in the fire, and ground it to powder, and strewed it upon the water, and made the children of *Israel* drink of it †." "And I took your sin, the calf which ye had made and burnt it with fire, and stamped it, and ground it very small, even until it was as small as dust; and I cast the dust thereof into the brook that descended out of the mount ‡."

(q) The fact is here perhaps too strongly represented; no mention being made in the text of the powder'd gold mixing with the water; in which, if only powdered, it should rather seem to subside.

Dr. Stahl several years since has shewn an easy method of dissolving gold in water; by barely melting the gold with a suitable proportion of the liver of sulphur, or brimstone and pot-ash, powdering the mass, and throwing it into water †. And in another passage of *Borrichius*, the thing is supposed known to the proficient in chemistry **.

(r) The best accounts, with more probability, make him only a petty prince of some island in the *Archipelago*, as *Sicily*, *Cyprus*, or *Lemnos*, tho' there are said to have been four of the name ††.

(s) *Diod Sic L.*

(t) *Plutarch. Is. & Os. 364. C.*

(u) *Steph. Byzantin. in Voce "Αστυνός."*

(x) *Id. ib.*

* *Acts viii. 22.*

† *Exod. xxxiii. 20.*

‡ *Deuteron. ix. 21.*

|| See *Stahl. Schediasm. in Vitul. Aur. p. 585 — 606.*

** See *de Ort. Chem. p. 47, 48.*

†† See *Cicer. de Natur. Deor. L. V. & Borrich. de Ort. Chem. p. 62.*

11. Add, that at *Memphis*, a city of *Egypt*, there were priests of *Vulcan* (y), and a magnificent temple to that God (z), with vestibles (a), and images (b); and his symbol there was a vulture (c), which is a bird of prey. Lastly, according to *Zeno* (d), *Jupiter* was also called *Hephaistos*, by extension to artificial fire; which name is evidently derived from the *Greek* ἥσπας, to be kindled, or burn. The same is countenanced by that happy coiner of epithets *Horace*;

— dum graves Cyclopum
Vulcanus ardens urit officinas (e).

As also by the more ancient comic poet *Plautus*; Quo ambulas tu, qui Vulcanum in cornu conclusum geris (f). All which particulars conspire to shew that the metallurgic part of chemistry was chiefly practiced among the *Egyptians*; and that chemistry, taken in this sense, as well as the name which denotes it, are of the earliest antiquity (g).

12. Many ages after, the name chemistry began to be applied to another thing; viz. the art of making pure gold out of the baser metals, by a true conversion, maturation, or at least, some extraordinary secret kind of separation; which art having been much cultivated, in more modern days, by the *Arabs*, was by them denominated *Alchemia*, and sometimes, by a little alteration, *Alchimia* (h).

Origin of
alchemy.

13.

(y) *Herod.* xi. 3

(z) *Id.* xi. 99.

(a) *Id.* ib. 102.

(b) *Id.* ib. 176. iii. 37.

(c) *Voss.* *Id.* G. iii. 573.

(d) *Diog. Laert.* vii. 47.

(e) Whilst scorching *Vulcan* heats
The *Cyclop's* load'd shop.

(f) Where goest thou with *Vulcan* in thy
lanthorn†?

(g) It is evident that chemistry, so far as it means only the separating and purifying of metals, to fit them for common uses, must have been ancient; tho' we need not go so far back for it as the fabulous ages, or the time of *Hermes*, supposed contemporary with *Saturn*, or with *Isis* and *Osiris*, the most ancient King and Queen of *Egypt*†.

(h) Alchemy is so far from being originally *Arabic*, that it does not appear the *Arabs* have any such word at this day; if either *Golius*|| or *d'Herbelot*** be of any authority; who both of them render what we call alchemy, in *Arabic*, by plain *kimia* or *kimya*. Some have observed that among the people, chemistry, properly so called, is restrain'd to the treating of vegetable subjects; and that it only takes its name by extension, in the preparation of metals and minerals; which the

Arabs call by a peculiar name, *Simia*. Add, that when their authors speak of chemistry in general, and the wonderful effect it produces, they always join the two names, *kimia wa simia*, i. e. *kimia* & *simia*.

Origin of Alchemy.

" 1. Having shewn the antiquity of chemistry, consider'd with regard to the art of metals; it remains to consider the same with regard to the making of gold, and finding the philosopher's stone.

" 2. Now, chemistry taken in this light is usually called *alchemy*, an *Arabic* word, form'd by prefixing the augmentative particle *al*, to denote it the most eminent, and sublime part of the art: as, of *gebra* is form'd *algebra*, of *kermes*, *alkermes*, &c. But it must here be remember'd, that the word *alchemy* has a double acceptation, respecting the two different things which it pursues: viz. (1.) The secret of making gold from any other metal. (2.) A universal medicine for the cure of all diseases; which is a distinction of the utmost moment, in an enquiry into the origin of alchemy.

" 3. Our first business then shall be to settle the æra of alchemy, as it proposes the making of gold. This, we venture to say,

* *Lib.* I. *Od.* IV.

† See *Le Clerc. Bibliothec. Univ. & Hist.* tom. 3.

** *Bibl. Orient.* p. 1005.

† *Amphitr.* i. 185.

|| *Lex. Arab.* p. 1087, & 2066.

The History of CHEMISTRY.

13. *Suidas* who lived in the tenth century observes, that *Dioclesian*, who reign'd in the twenty last years of the third century, ordered all the books of this art to be burnt, on account of some conspiracies which the *Egyptians* were forming against the *Roman* state. He says, that as to "Chemistry, or the art of making gold and silver; *Dioclesian* procured the chemical books to be sought out, and burnt; because the *Egyptians* rebelled against him.---He used them with great severity and cruelty: ordering all the writing of the ancients concerning the chemistry of gold and silver to be search'd out, and burnt: that the *Egyptians* might not have a supply of wealth from that art; nor from their wealth, a stock of confidence

" and

" say, is not near so ancient as the art of metals; nor do we find any trace thereof before the third century. The chemists indeed go higher, and will abate nothing of the age of *Adam*. That patriarch, they say, was no stranger to the art of making gold, which he taught his descendants; tho' it had the fortune to be lost at the flood; and was only restored by *Moses* and his sister, from whom it has been handed down without interruption thro' the succeeding ages. But a matter of history is only to be demonstrated from monuments of history; and the ancient historians, poets, &c. are all perfectly silent as to any such thing. Neither *Orpheus*, *Homer*, nor *Hesiod*, nor any of the *Latin* scholiasts or antiquaries, or their commentators, mention any thing of the matter. And what would not the poets have given for such a boundless field of fiction and fancy? *Aristotle*, assisted by *Alexander* the great, master of all the antiquities of the *Persians*, *Chaldeans*, *Babylonians*, *Egyptians*, *Hebrews*, and *Greek*; this *Aristotle*, who described the properties of bodies, and all their physical changes, has not one word of the philosopher's stone: and can it then be thought possible the *Egyptians*, the people of *Asia* and *India* should have had any such secret? *Theophrastus* was *Aristotle*'s disciples; he writ of vegetables, stones, metals, and fossils, of gold, silver, mercury, and all the minerals, and beside his own stock of knowledge, was master of all the works of *Aristotle*: yet he takes no notice of transmutation. *Pliny*, that indefatigable naturalist, who compiled his work from so many thousands volumes; who search'd with unwearied pains into every thing strange, and out of the way; and who has comprehended almost all the monuments of art and nature within his pandects, never mentions any thing like a philosopher's stone, which should transmute metals, in all their substance, into gold. In all the historians, we find nothing to

" countenance this imaginary antiquity; nothing that shews it to have been talk'd of even in *Galen*'s time. For we bar the conjectures which the chemists use to advance on this occasion; as in truth they are no better than chimeras. What, for instance, can be more than to find the doctrine of making gold couched in the story of the *Argonauts*, the books of *Moses* and the revelation?"

4. For the antiquity of alchemy, consider'd as it aims at an universal remedy; or even at any remedy at all, it appears to be the latest branch of the art. Many are of opinion, that all preparations of metals, and other matters, for medicinal uses, were utterly unknown to the ancients; and first introduced by *Paracelsus*.

5. *Borrichius*, however, pleads strenuously for the antiquity of this branch; and employs much learning and subtilty to prove it antediluvian, and *Hermes Trismegistus* the author. Now, the fate of every art is only to be exhibited from the genuine monuments of history; and some author should here be produced to warrant this antiquity; by relating, that the art was invented, or cultivated in such or such an age.

6. But *Borrichius* will have it ancient without any such voucher: the chief ground he goes on, is a passage in *St. Jerom*, who speaking of *Hermes*, says he was a great physician. But is this a proof of his having the art of making gold out of baser metals, and of making a medicine by means thereof that should cure all diseases?

7. History, in effect, affords no ground for the opinion: *Moses*, supposed the oldest writer extant, and those who immediately succeeded him, are silent on the point; and yet *Moses* was an adept in all the learning of the *Egyptians*, and relates the origin of all the arts from *Adam* to *Noah*; and had a fair opportunity for this, in treating of the lepra in *Leviticus*, had he known it. From *Moses* to the *Babylonish* captivity, we have no historian: the first that appears,

"and courage to raise any more rebellions (i)." And the same author elsewhere (k) goes much higher, asserting in express terms that "the golden fleece, which Jason and the Argonauts carried over the Pontic sea to Colchis, was only a book wrote on skins, which taught the manner of making gold by the chemical art." This, if he had given proper vouchers for it, would have carried back the antiquity of chemistry thirteen centuries before Christ; in which time the science must have been both known, practis'd, and even written of; so as to prove the occasion of the painful and hazardous expedition, which the Argonauts embarked in: but what discredits the relation is, that Moses and the other sacred writers, as also Sanconiatbo, Orpheus, Homer, Hesiod, Pindar, Herodotus, Thucydides, Hippocrates, Aristotle, Theophrastus, Dioscorides, Galen and Pliny should have been utterly silent on this head; when the design and scope of their writings, as well as the age wherein they lived, and the opportunities they had of Information should indisputably have led them to have made mention thereof. Nor have we any conviction to the contrary from those passages of Pliny concerning malleable glass (l); or of Dion Cassius (m) concerning the same being rejected by Tiberius; nor another passage of Pliny (n), relating to Caligula, who with great difficulty procured a little fine gold out of orpiment; since these testimonies only prove that such operators were proficient in the Art of glass and assaying (o).

14. It must be owned however that Julius Maternus Firmicus (p), who wrote in the beginning of the fourth century (q) speaks of the science of al-
Antiquity a-
mong the
Greek clergy.
 chemistry as a thing well known in those days; if the text of this author may be

appears, is the Phœnician, Sanconiatbo, who was cotemporary with Zorobabel: to him we are indebted for what we know of the Phœnician and Grecian antiquities; but he has not a word of the philosopher's stone, or the grand medicine. Herodotus and Thucydides afford us no more light; and yet the former is very particular in enumerating the arts of the Egyptians. Nor does Dioscorides, who travell'd thro' Chaldea, Persia, Babylon, Egypt, Africa, Europe, and other countries, and collected every thing relating to the art of physic, mention any thing of an universal medicine. Aëtius likewise, who collected his Tetrabiblos from all the writers then known, and from a thousand now lost, is silent in this particular; though he is very express in rehearsing all the arcana for the several diseases; his work being a kind of index, or inventory of all antiquity, Ask Hippocrates, who according to Zoranus's account, pass'd thro' all Egypt, Africa, and the coasts of the Mediterranean sea, to make discoveries and improvements in his art; and ask Galen too, who was a no less laborious enquirer, why they all took such pains, by slow imperceptible means to improve their art,

when they had it in their power to cure all the diseases of the human body by a single preparation, known to so many persons? Is it possible that Galen, who publish'd an account of all the sects and writers among the physicians, should be so inadvertent as to forget so singular a body of enthusiastical quacks, had they been then in being? A pretender to an universal remedy could never have escap'd the gall of his pen.

(i) See Suid. in voce Xyrius.

(k) Id. in voce Διόγ.

(l) Hist. Nat. xxxv. 25.

(m) L. vii. p. 67.

(n) Hist. Nat. xxxiii. 4.

(o) Nor are the testimonies themselves clear, and express to the points here mentioned; those of Pliny being given with some sort of diffidence, or suspicion of their truth, especially as to the art of making glass malleable. See the places above cited.

(p) Joseph Scaliger takes this to be the most ancient author extant that mentions al-
 chemistry, tho' he wrote in Latin, and only in the time of Constantine the Great.

(q) III Mathes. 55.

* See Le Clerc. Hist. de la Médecine, p. 770.

be allow'd for genuine. *Aeneas Gazæus*, who lived at the close of the fifth century, speaks likewise of it in his *Theophrastus*, or treatise of the immortality of the soul, where he mentions it as a matter publicly known, and asserts that "those who are skilful can take silver and lead, and changing their former natures, convert them into the finest gold (r)". *Anastafius* the *Sinaite* (s), half an age after, according to the computation of *Vossius* (t); or at least after the middle of the seventh century, as *Fabricius* more maturely fixes his age (u), speaks somewhat more expressly, and says, "For the scripture, not desiring, or teaching us to become refiners, lapidaries, or jewellers, says thus (x)." 11

Ecclesiasticks amongst the Greeks, the chief, if not the first writers, on alchemy.

15. In the seventh century *Georgius Syncellus* writ professedly on the art. He was succeeded by a multitude of authors in alchemy, whose manuscript pieces are still found in the libraires of *Rome*, *Venice* and *Paris*, all written in the *Greek* language; but in a stile which shews the barbarism of their age, and also that most of them were ecclesiasticks by profession. A catalogue of these, as given by *Borrichius* (y) and others, is here subjoined.

Catalogue of unpublished Greek manuscripts treating of alchemy.

Συνίσταται. Cujus & tractatus de lapide Philosophorum, est in Bibliotheca Lugduno-Batavæ Academiæ.

Συνίσταται. φιλοσοφίας εἰς βιβλίον Δημοκρίτου. Totus tractatus apud Fabric. Bibl. Gr.

Σωσίμου ὁ μέγας, ὁ θεῖος, ὁ παναπολίτης. ex παναπολὶ Αἰγυπτὶ urbe. Libri xxiv. Ἰμῶν ad Θεοφείαν. Cujus titulus, Σωσίμου τοῦ παναπολίτου γνῶσις γραφὴ, περὶ τῆς ἱερᾶς, καὶ θείας τέχνης τοῦ χρυσοῦ, καὶ ἀργυρίου ποιήσεως. & Σωσίμου περὶ ἱερῶν, καὶ καμίνων.

Ἰωάννης. ὁ Πλουτάρχου. ὁ Ἀλεξάνδρου.

Ἰωάννης. περὶ χρυσοποιήσεως.

(r) *Biblioth. Patr.* vol. 2. p. 373.

(s) Or monk of Mount *Sinai*, and probably afterwards patriarch of *Antioch* *.

(t) *Voss. Id. G. l. I.* p. 25.

(u) *Bibl. Gr.* vol. ix. l. v. P. v. p. 313.

(x) The *Greek* passage here quoted, without any reference, has its difficulties; so that we doubt whether we have given the genuine sense of it; and can by no means perceive either the clearness or pertinency of it to the present point; viz. alchemy, or the art of making gold; we therefore here give the original

16. (1) *Synesius*; whose treatise of the philosopher's stone is in the library of *Leyden*.

(2) *Synesius the philosopher*, on the book of *Democritus*, published entire in *Fabricius* (z).

(3) *Zosimus the great, the divine, the Panapolite, of Panapolis, a city of Egypt, wrote xxiv books of imouth, or chemistry, to Theosebia, entitled Zosimus, the Panapolite, his faithful description of the sacred and divine art of making gold and silver; also of instruments and furnaces.*

(4) *Olympiodorus, the Alexandrian.*

(5) *Heliodorus, on the making of gold.*

Ἰωάννης passage, as apprehending that the learned author might see more in it than we do; ἀγαθὴ χρυσοχόους ἡμᾶς, καὶ λιθεύς, καὶ χαμινοτά χρυσοκλάτων λίθων ἀπεργάζεσθαι, ἡ γραφὴ, βεβαιώσῃ, καὶ πειραίσῃ, ταῦτα φησί. If indeed the word here wrote χρυσοχόους, gold-melters, were χρυσοποιούς, gold-makers, it would be to the purpose †.

(y) *De Hermetis Egyptiorum & Chymicarum Sapientia.* p. 78, 80. seq.

(z) *Bibl. Gr. L. V. c. 22. p. 222. Gr. & Lat.*

* See *Le Clerc. Suppl. to Moreri*, under *Anastafius*.

† See *Anastaf. Anagog. Contempl. in Hexam. Lib. viii. Bibl. Patrum. Vol. ix. p. 898. D.*

Ἰωάννης Ἀρχιεπίσκοπος, τὸ ἐν ἁγίᾳ πόλει, περὶ τῆς ἁγίας τέχνης.

Στέφανος ὁ φιλόσοφος Ἀλεξανδρεὺς οἰκουμένης, περὶ τῆς ἱερᾶς, καὶ θείας τέχνης τὸ χρυσοῦ ποίησις. Hujus & Manusc. in Bibliotheca Academiae Lugd. Batavæ.

Ἦρος. χημεικὰ.

Σοφῆς ἐν Περίῳ.

Ἐκ τοῦ σέculo sexto circumlatus, laudatus a Zosimo.

Διόσκουρος ὁ ἱερεὺς μεγάλῃ Σεραπίδι ἐν Ἀλεξανδρίᾳ.

Ὁράσιος ὁ ἐν Ἀιγύπτῳ περὶ Πετασίῳ περὶ τῆς ἱερᾶς καὶ θείας τέχνης.

Μωσῆς προφῆτης περὶ χημεικῆς συντάξεως.

Μαρία Ἑβραία.

Πελάγιος φιλόσοφος περὶ τῆς θείας, καὶ ἱερᾶς τέχνης.

Πορφύριος.

Ἐπιβύχιος. vel Ἐπιβήχιος.

Κομάριος φιλόσοφος, καὶ ἀρχιερεὺς, διδάσκων τὴν Κλεοπάτρῃ τὴν θύειν καὶ ἱερὰν τέχνην τοῦ λίθου τῆς φιλοσοφίας.

Κλεοπάτρα ἡ γυνὴ Πτολεμαίου τοῦ βασιλέως. Eadem περὶ σταθμῶν καὶ μέτρων.

Κοσμάς ἱερομονάχῃ ἱερμενίᾳ τῆς χρυσοποιίας.

Ἀγαθοδαίμων εἰς τὸν χημεικὸν Ὀρφικὸν συναγωγῇ, καὶ ὑπόμνημα.

Πάππος φιλόσοφος ἔργον.

Ἡρακλεῖος ὁ βασιλεὺς.

Σαλμάνῃ Ἀραβὸς μέθοδος.

Χριστιανὸς περὶ τοῦ θείου ὕδατος.

Θεόφραστος φιλόσοφος περὶ τῆς θείας τέχνης.

Ἀρχέλαος φιλόσοφος περὶ τῆς θείας τέχνης.

Κλαυδιανὸς.

Σέργιος.

Ἀνώνυμος φιλόσοφος περὶ χημείας.

(6) John, the high-priest, in the holy city, concerning the holy art.

(7) Stephen, the universal philosopher, of Alexandria, his account of the holy and divine art of making gold: preserved in MS. in the library of Leyden.

(8) Orus, his chemical pieces.

(9) Sophar, in Persia.

(10) Hermes, extant in the sixth century, cited by Zosimus.

(11) Dioscurus, priest of the great Serapis, in Alexandria.

(12) Oftanes, of Egypt, to Petasius, concerning the sacred and divine art.

(13) Moses, the prophet, on chemical composition.

(14) Mary, the Jew.

(15) Pelagius, the philosopher, on the holy and divine art.

(16) Porphyry.

(17) Epibychius, or Epibechius.

(18) Comarius the philosopher and high-priest, his piece instructing Cleopatra in the divine and holy art of the philosopher's stone.

(19) Cleopatra, wife of king Ptolemy. The same on weights and measures.

(20) Cosma, the monk, his interpretation of the art of making gold.

(21) Agathodæmon, his collection and comment on the oracle of Orpheus.

(22) Pappus, the Philosopher, his work.

(23) Heracleus, the king.

(24) Salmana Arabus, his method.

(25) Christianus, on holy water.

(26) Theophrastus, the philosopher, on the divine art.

(27) Archelaus, the philosopher, on the divine art.

(28) Claudian.

(29) Sergius.

(30) An anonymous philosopher, on chemistry.

Μιχαὴλ Πέλλας πρὸ χρονοποίας.
Vixit sub Constantino Duca. Borrich.
pag. 79. anno 1060. post Christ.

Ἰσὺς προφήτης τῷ υἱῷ Ὁρῷ.

Βλεμμίδας ἔργον χημεινῶν.

Νικήφορος.

Δημοκρίτου βιβλίον πρὸ φυσικῶν καὶ λευκώσεως.

Δημόκριτος φυσικὰ καὶ μυστικά.

Ἱερόθεος φιλόσοφος πρὸ λίθου τῶν φιλοσόφων.

Ἰσακ Μοναχός, ὅπως διὰ ἐνρίσκων μεθοδὸν ἀργύρου.

(a) See Borrich. *Herm. Egypt.* p. 79.

(b) The author's account of the ancient Greek chemists being somewhat jejune, as well as otherwise defective; we think it necessary to subjoin a more full, and distinct *notitia*, or recital of them; the rather, as there is little likelihood of ever seeing them publish'd, how earnestly soever many have wished for it. *Leo Allatius* had a design to have given an edition of them; but the corruption of their text, the obscurity, the quaintness, and inaccuracy, of their symbols, their continual allegories, their high-flown figures and hyperboles, will go near to intimidate any less laborious editor.

The principal copies are in the emperor's library at Vienna, the king of France's at Paris, the Elizabeth library at Breslaw, and that of the duke of Saxa-Gotha: besides several particular pieces in the library of the Escorial, and the Bodleian.

The Vienna copy of this body of Greek chemists, was written by *Corn. Naupliensis*, a native of the Morea, residing at Venice in the year 1564.

The Catalogue is as follows.

1. ΕΡΜΗΣ, or Hermes; extant in MS. in the elector of Bavaria's library at Munich *

2. ΕΡΜΟΥ φυσικὰ βαφὰς, or Hermes's physical tinctures.

3. Ἀρχὴν βιβλίον, or book of chemical initiation.

4. ——— A fragment of chemistry in Greek and Latin, extant in MS. in the Vienna library, Cod. L. I. & L. II. n. 8.

5. ——— Fragments, in Greek extant in MS. in the library of Gotha.

(31) Michael Psellus, on the making of gold. He lived under Constantine Duca, in the year of Christ 1060 (a).

(32) Isis, the prophetess, to her son Orus.

(33) Blemmidas, his chemical work.

(34) Nicephorus.

(35) Democritus, his book to Leucippus.

(36) Democritus, his physical and mystical writings.

(37) Hierotheus the philosopher, concerning the philosopher's stone.

(38) Isaac the monk; how to find the method of making silver (b).

17.

6. ——— Liber de arte alchemiz, extant in MS. in the Bodleian library, being given by Sir Kenelm Digby; and found likewise in the Elizabeth library at Breslaw.

7. ——— Secreta in MS. in the Elizabeth library at Breslaw.

8. ——— Tabula Smaragdina, seu verba secretorum, with other chemical pieces found in MS. in the Bodleian library; and with the commentaries of Wilh. Christop. Kriegsmannus, in *Manget's Bibliotheca chymica curiosa*. Genes. 1702. fol. T. II. p. 380.

9. ——— A piece in Leonine verses, ext. in MS. in the Bodleian library, being part of the donation of Elias Ashmole.

10. Liber de compositione, translated from the Arabic, extant in the philosophia chymica IV. vetustiss. scripta. Francof. 1605. 8vo.

11. ——— de lapidis philosophici secreto tr. aureus; divided into vii chapters, and illustrated with scholia by an anonymous writer; extant in the fourth volume of the *theatrum chymicum*. Strasb. 1613. 8vo. p. 627. and in *Manget's Bibl. Chym.* T. I. p. 400.

12. ἈΓΑΘΟΔΑΪΜΩΝ εἰς τὴν χρυσοποίησιν ὉΡΦΕΟΥ συναγωγή καὶ ὑπόμνημα, i. e. *Agathodæmon's* collection and memorial on the oracle of Orpheus, in Greek, extant in MS. in the king's library at Paris, and in that of Fabricius at Hamburg †.

13. ἈΓΑΘΟΔΑΪΜΩΝΟΣ χρυσοποίησις, i. e. *Agathodæmon's* art of making gold, extant in MS. in the library of the Escorial, and in that of the elector of Bavaria at Munich.

14. ——— a fragment of chemistry, in MS. Greek and Latin, preserved in the Vienna library,

* Supposed to have flourished in the XXth century before Christ.

† In the XIXth century before Christ.

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library, Cod. LI and LII, n. 8. and in the library of Gotha.

15. *ΠΙΣ*, *προφήτης*, τῷ υἱῷ Ἡρῶ, i. e. *Ipsi* the prophetess to her son *Herus*, in MS. in the king's library at Paris, and in that of Fabricius at Hamburg (1).

16. *ἹΠΟΥ* *χημικῶν*, i. e. Chemical writings of *Horus* (2).

17. *ΣΟΦΑΡ* ἢ *ἡ Πισφῶ*, i. e. *Sophar* in Perside, in MS. at Munich in the electoral library.

18. *ΜΩΣΗΣ*, *προφήτης*, καὶ *χημικῶν συνθέσεων*, i. e. *Moses*, the prophet, on chemical composition (3).

19. *ΜΩΣΕΩΣ* *ἀποκρυφῶν*, i. e. *Moses's* chemical secret, entitled, duplication, Greek and Latin, extant in MS. in the Vienna library, Cod. LI. and LII. n. 26. and in Greek alone, in the royal library at Paris, and that of Fabricius at Hamburg.

20. *ΜΑΡΙΑ* *Ἑβραῖα*, i. e. *Mary the Hebrew*; extant in MS. in the electoral library at Munich (4).

21. ——— *Practica in artem chemicam*, extant in MS. in the Bodleian library.

22. ——— *Practica lapidis philosophici*, extant in the collection of writers artis auriferæ, Basil. 1593. 8vo. vol. I.

23. *ΟΣΤΑΝΟΥ*, *φιλοσόφου*, πρὸς *ΠΙΤΑΪΟΝ* *πρὸς τὸν ἱερεῖα ἄνθρωπον*, i. e. *Ostanes* the philosopher's letter to *Pelasus* on the sacred and divine art (on the composition, use, and effect of the water of mercury) extant in MS. Greek and Latin. in the Vienna library, Cod. LI. and LII. n. 3. in the royal library at Paris, in that of the elector of Bavaria at Munich, in that of Gotha, in the Ambrosian library at Milan, in If. Vossius's library, Cod. 147, in the Elizabeth library at Breslaw, in that of Fabricius at Hamburg (5).

24. *ἸΩΑΝΝΟΥ*, *Ἀγγέλου*, τῷ *ἱεροῦ πόλεως*, *πρὸς τὸν ἱερεῖα ἄνθρωπον*, i. e. *John*, priest, in the holy city, on the sacred art; in Greek, extant in MS. in the royal library at Paris, in the electoral library at Munich, and in Fabricius's library at Hamburg (6).

25. *ΔΗΜΟΚΡΙΤΟΥ*, *Ἀβδηρίτου*, φυσικῶν φιλοσοφῶν, *πρὸς χρυσὸν καὶ ἀργύρον, καὶ λίθους, καὶ πορφύρας*, i. e. *Democritus the Abderite*, the natural philosopher, on the tincture of gold and silver, and on precious stones and purple; in Greek, extant in MS. in the library of the Escorial, in the elector's library at Munich, and in the Elizabeth library at Breslaw (7).

26. *ΔΗΜΟΚΡΙΤΟΥ*, φυσικῶν καὶ μυστικῶν, i. e. *Democritus's* physical and mystical pieces; Greek and Latin, extant in the Vienna library, Cod. LI. and LII. n. 4. in the library of the Escorial, the royal library at Paris, the library of Gotha, the Ambrosian library at Milan, and the Elizabeth library at Breslaw.

————— In Latin, with the commentaries of *Sinesius* and *Pelagius*, translated from the Greek by *Dominicus Pigimentius*—To which are added nine centuries of memorable things; printed at Cologne, 1572, 12mo: and with the scholia and commentaries of *Synesius*, *Pelagius*, *Stephanus Alexand.* and *Mich. Piellus*, at Padua, 1573. 8vo.

27. *ΚΟΜΑΡΙΟΥ*, *φιλοσόφου* *ἑρμηνεύς* *διδασκαλίας* *τῆς ΚΑΘΟΛΙΚΗΣ* *τῆς θείας καὶ ἱερᾶς τέχνης* *τῷ λίθῳ τῆς φιλοσοφίας*, i. e. The work of *Comarius*, the philosopher and priest, teaching *Cleopatra* the divine and sacred art of the philosopher's stone; in Greek, extant in MS. in the royal library at Paris, and in that of Fabricius at Hamburg (8).

28. *ΚΑΘΟΛΙΚΑ*, ἢ *γυνὴ τοῦ ΠΤΟΛΕΜΑΙΟΥ*, i. e. *Cleopatra*, wife of *Ptolemy*; in Greek, extant in MS. in the elector of Bavaria's library at Munich (9).

————— In τῷ *ΚΑΘΟΛΙΚΩ* *τῶν μέτρων καὶ ῥαβδῶν*, i. e. a chemical fragment of *Cleopatra* concerning weights and measures; Greek and Latin, extant in MS. in the Vienna library Cod. LI. and LII. n. 11. and in Greek in the library of Gotha.

29. Τῷ *ΚΑΘΟΛΙΚΩ* *τῶν μέτρων καὶ ῥαβδῶν* *καὶ μέτρων ἑρμηνεύς* *κατὰ πλάτος* *πρὸς τὴν ἐκτέλεσιν* *ἐκείνης μυστικῆς καὶ ἁγίας καὶ ὁρμητικῆς καὶ δραχμῆς καὶ γράμματος*, i. e. *Cleopatra's* large explanation of weights and measures, for the ready finding any mina, pound, ounce, drachm, and scruple; in Greek, extant in MS. in the royal library at Paris, and that of Fabricius at Hamburg.

30. *ΚΑΘΟΛΙΚΑ* *τῶν χρυσοποιῶν*, i. e. *Cleopatra's Chrysopæia*, or art of making gold, consisting almost wholly of ænigmatical characters; in Greek and Latin, extant in MS. in the Vienna library Cod. LI. and LII. n. 14. and in Greek in the library of Gotha.

31. *ΠΟΡΦΥΡΙΟΥ*, i. e. *Porphyry*, in Greek, found in MS. in the electoral library at Munich (10). *Tract. chym.* MS. extant in the library of If. Vossius.

32. *Ἡ ἸΑΜΒΑΙΧΟΥ* *ποίησις*, i. e. *Jamblichus's* poetry, or art of making gold; in Greek extant

(1) In the XIXth century before Christ.

(3) In the XVth century before Christ.

(5) In the Vth century before Christ.

(7) In the Vth century before Christ.

(9) In the Ist century before Christ.

(2) In the XVIth century before Christ.

(4) In the XVth century before Christ.

(6) In the Vth century before Christ.

(8) In the Ist age before Christ.

(10) In the IIIrd century after Christ.

exant in MS. in the royal library at Paris, and in that of Fabricius at Hamburg.*

34. ΗΛΙΟΔΩΡΟΥ, φιλοσόφου, πρὸς ΘΕΟΔΩΡΙΟΝ, τὸν μέγαν βασιλέα, περὶ τῆς τῶν φιλοσόφων μυστικῆς τέχνης διαρχῆς ἰαμβικόν, i. e. Heliodorus the philosopher's iambic poem to the Emperor Theodosius the Great, on the mystic art of the philosophers, consisting of 268. verses, in Greek and Latin; extant in the library at Vienna, Cod. LI. and LII. n. 29. in Greek alone, in the royal library at Paris, in those of Wolfenbuttel, Bern, the Ambrosian at Milan, and the Elizabeth library at Breslaw. Besides another MS. in Greek, consisting of 269. verses, extant in the royal library at Paris, and printed in Fabricius's *Bibl. Græc.* Vol. VI. pag. 790. seq.

35. ΦΙΛΙΠΠΟΥ, Σιδίτου, βασιλὸς τῷ πατρὶ Πίρσαις ἐξουρημὸν χαλκῷ, καὶ βασιλὸς τῷ Ἰνδῷ σιδήρῳ, i. e. Philip the Sidite's tincture of Persian copper, and tincture of Indian iron, in Greek and Latin; extant in the Vienna library, Cod. LI. and LII. n. 17. and in Greek in the library of Gotha †.

36. ΕΠΙΒΥΧΙΟΥ, or ΕΠΙΒΕΧΙΟΥ, i. e. Epibychius, or Epibechius, in Greek; extant in the library of the elector of Bavaria at Munich.

37. ΖΩΣΙΜΟΥ, τῷ Πανοπολίτῃ, χημικὰ, *five libri xxiv.* τῆς ἑνὸς περὶ ΘΕΟΣΕΒΙΑΝ ἀδελφῆς, i. e. Zosimus the Panopolite's Imouth, or xxiv. books on the chemical art, to his sister Theosebica, in Greek; extant in MS. in the king's library at Paris.

38. ——— γνησία γραφὴ περὶ τῆς θεῆς καὶ διαίας τέχνης τῆς τῷ Θ. καὶ Δ. σωτηρίας, i. e. a genuine description of the sacred and divine art of making gold and silver; extant in Greek, in MS. in the royal library at Paris, and in that of Fabricius at Hamburg.

39. ΖΩΣΙΜΟΥ τῷ θεῷ περὶ ἀρετῆς καὶ ἐρμηνείας, i. e. Zosimus, the divine, his book concerning virtue and interpretation; extant in MS. in Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 7. In Greek, in the king's library at Paris, in the library of Gotha, the Elizabeth library at Breslaw, that of Fabricius at Hamburg, and the Ambrosian at Milan.

40. ——— περὶ ΘΕΟΔΩΡΩΝ νεφέλαις, i. e. Chemical chapters to Theodorus, extant in Greek and Latin, MS. in the imperial library at Vienna, Cod. LI. and LII. n. 12. In Greek, in the king's library at Paris, and in Fabricius's library at Hamburg.

41. ——— περὶ ὀργάνων καὶ καμίνων, καὶ περὶ τῷ θεῷ ὕδατος, i. e. Of chemical instruments and furnaces, and of the divine water; extant in Greek and Latin, MS. in the emperor's li-

brary at Vienna, Cod. LI. and LII. n. 13. In Greek, with the addition of figures in the royal library at Paris, the Elizabeth library at Breslaw, and that of Fabricius at Hamburg.

42. ——— περὶ ὀργάνων καὶ καμίνων, γνησία ὑπομνήματα, i. e. Genuine commentaries concerning chemical instruments and furnaces; extant in Greek and Latin, MS. in the Vienna library, Cod. LI. and LII. n. 15.

43. ——— περὶ αὐτῆς συνόδου ἰδίων, i. e. On the virtue of the composition of waters; extant in Greek MS. in the king's library at Paris, the Ambrosian at Milan, and that of Fabricius at Hamburg.

44. ——— περὶ τῆς Ἀσβεστοῦ, i. e. On the asbestos; extant in Greek MS. in the king's library at Paris, and in that of Fabricius at Hamburg.

45. ——— μυστικὴ βίβλος, i. e. Mystical book; extant in Greek in the same libraries.

46. ——— Divers small pieces; in Greek MS. in the ducal library at Gotha, the elector of Bavaria's library at Munich, and the Elizabeth library at Breslaw.

47. ΚΛΑΥΔΙΑΝΟΥ, i. e. Claudian; extant in Greek MS. at Munich in the elector's library.

48. ΔΙΟΣΚΟΡΟΥ, ὁ κερὶς τῷ μεγάλῳ Σεραπίδῃ τῷ ἐν Ἀλεξανδρίᾳ, i. e. Dioscorus, priest of the great Serapis at Alexandria; extant in MS. in Greek in the elector of Bavaria's library at Munich.

49. ΣΥΝΕΣΙΟΥ, φιλοσόφου, πρὸς ΔΙΟΣΚΟΡΩΝ, τῷ ἐν Ἀλεξανδρίᾳ εἰς βίβλον ΔΗΜΟΚΡΙΤΟΥ, ὡς ἐν σχολίῳ, i. e. Synesius the philosopher's epistles to Dioscorus, priest of the great Serapis at Alexandria, serving as scholia on Democritus's book (of natural and mystical things); extant in MS. Greek and Latin in the Vienna library, Cod. LI. and LII. n. 5. and in the Wolfenbuttel library; in Greek in the elector's library at Munich, the library at Gotha, the Elizabeth library at Breslaw, and the Ambrosian library at Milan. It has also been publish'd by Fabricius in his *Bibl. Græc.* I. V. c. 22. Vol. 8. p. 233. with the Latin version of Dominicus Pizimentius, which alone had been printed before, together with Democritus, at the end of Ant. Mizaldus's *Memorabilia.* Cologne 1572. 12mo.—With Democritus, Pelagius, and Psellus at Padua 1573. 8vo.—And with the Tumba Semiramidis hermetice figillata of a modern writer, Norimberg 1717. 8vo. An English version, made from the copy in the library of Vienna, is printed at the end of the English translation of Basil Valentine, London 1678. 8vo. A High-Dutch translation has also been published by Fred. Rothscholzius, Altorf. 1718. 8vo.

* In the IVth century after Christ.

† In the Vth century after Christ.

50. — Treatise of the philosopher's-stone, in MS. in the university library at Leyden.

51. **ΣΑΛΑΚ**, Μοναχός, ὅστις δὲ ὑπόκειται μετὰ τοῦ ἀργύρου, that is, *Salac* the monk, on finding the method of silver; extant in MS. Greek and Latin, in the king's library at Paris.

52. **ΟΛΥΜΠΙΟΔΟΡΟΥ**, φιλοσόφου Ἀλεξανδρείας, περὶ ΠΕΤΑΣΙΟΝ τῆς βασιλῆως Ἀρμενίας ἐκ τῆς κατ' ἐξουσίαν ΖΩΣΙΜΟΥ ἥσα ἀπὸ ΕΡΜΟΥ καὶ τῶν φιλοσόφων ἡσάν ἀρμῆνα, that is, *Olympiodorus* the *Alexandrian* philosopher's commentary, according to the operation of *Zosimus*, on those things delivered by *Hermes* and other philosophers concerning chrysopoeia, or the art of making gold; extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 23. In Greek, in the king's library at Paris, in the elector of Bavaria's library at Munich, the library of Gotha, the Elizabeth library at Breslaw, and in that of Fabricius at Hamburg.

53. **ΘΕΟΦΡΑΣΤΟΥ**, φιλοσόφου, περὶ τῆς ἐν τῇ θείᾳ τέχῃ διὰ τῶν ἱερῶν, that is, *Theophrastus* the philosopher's iambic poem on the divine art, consisting of 265 verses; extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 30. in Greek in the king's library at Paris, the elector's library at Munich, the Elizabeth library at Breslaw, the Ambrosian at Milan, and that of Fabricius at Hamburg.

54. **ΙΕΡΟΘΕΟΣ**, φιλοσόφου, περὶ τοῦ τοῦ φιλοσόφου, that is, *Hierotheus* the philosopher, on the philosopher's stone.

55. **ΙΕΡΟΘΕΟΥ** περὶ τῆς ἱερᾶς τέχνης, that is, *Hierotheus* on the sacred art, (of making gold) written in prose; extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 28. In Greek, in the royal library at Paris, the library of Gotha, the Ambrosian library at Milan, and that of Fabricius at Hamburg.

56. **ΙΕΡΟΘΕΟΥ**, φιλοσόφου περὶ τῆς αὐτῆς θείας καὶ ἱερᾶς τέχνης, διὸς ἔχει ἱερῶν, that is, *Hierotheus* the philosopher's poem on the divine and sacred art, consisting of 230 iambic verses; extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 31. In Greek, in the king's library at Paris, in the library of Gotha, the Ambrosian library at Milan, the Elizabeth library at Breslaw, and that of Fabricius at Hamburg.

57. — A like poem in Greek, consisting of 64 verses, extant in MS. in the king's library at Paris, and in that of Fabricius at Hamburg.

58. **ἈΡΧΕΛΑΟΥ**, φιλοσόφου, περὶ τῆς αὐτῆς ἱερᾶς τέχνης διὰ τῶν ἱερῶν ἱερῶν, that is, *Arche-laus*, the philosopher, on the sacred art,

composed in iambic verses, 322 in number; extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 32. In Greek, in the king's library at Paris, the Elizabeth library at Breslaw, the library of the Escurial, the duke of Bavaria's library at Munich, and that of Fabricius at Hamburg.

59. Ἀνώνυμος φιλόσοφος περὶ χημίας, i. e. An anonymous philosopher on chemistry; extant in MS. Greek, in the Elizabeth library at Breslaw.

60. Ἀνώνυμος περὶ τοῦ ποιεῖν that is, An anonymous philosopher on the making gold; extant in MS. in the king's library at Paris, and that of Fabricius at Hamburg.

61. Ἀνώνυμος περὶ λευκαντίας, An anonymous writer on the art of whitening; extant in MS. in Greek, in the Ambrosian library at Milan.

62. — περὶ τοῦ ὕδατος τῆς λευκαντίας, that is, on the divine whitening water, and other parts of the art of making gold; extant in MS. Greek and Latin in the Vienna library, Cod. LI. and LII. n. 6. In Greek, in the king's library at Paris, the Elizabeth library at Breslaw, and that of Fabricius at Hamburg.

63. **ΠΛΑΤΩΝ**, that is, *Plato*; extant in MS. in Greek, in the library of the Escurial, and that of the elector of Bavaria at Munich.

64. **ΠΕΛΛΑΓΙΟΥ**, φιλοσόφου, περὶ τῆς θείας καὶ ἱερᾶς τέχνης that is, *Pellagius*, the philosopher, on the divine and sacred art; extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 2. In Greek, in the king's library at Paris, in the Bodleyan at Oxford, the elector of Bavaria's library at Munich, the library of Gotha, the Elizabeth library at Breslaw, the Ambrosian library at Milan, and the library of Fabricius at Hamburg.

65. **ΕΥΓΕΝΙΟΥ**, περὶ τῆς ἱερᾶς τέχνης, that is, *Eugenius* on the sacred art; extant in MS. in Greek, in the king's library at Paris, and in that of Fabricius at Hamburg.

66. — Chemical secret composed chiefly in chemical characters; extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 17. and in the library of Gotha.

67. **ΚΟΣΜΑ**, ἱερομονάχου, ἡμενία τῆς ἐν τῇ χημείᾳ, that is, *Cosma* the monk's explanation of the art of making gold; extant in MS. Greek and Latin, in the king's library at Paris, and that of Fabricius at Hamburg.

68. **ΗΡΑΚΛΕΙΟΥ** ἡ βασιλῆως, that is, *Heraclius* the king; extant in MS. in Greek, in the library of the Escurial, and in that of the elector of Bavaria at Munich.

69. ΣΕΡΓΙΟΣ, that is, *Sergius*; extant in MS. Greek, in the elector of Bavaria's library at Munich.

70. Τὸ Χριστιανὸν περὶ τῶ Σελὺ ὀδωρῶν, that is, an anonymous Christian writer on the divine water to *Sergius* extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 10. in the king's library at Paris, and that of Fabricius at Hamburg.

71. ——— περὶ ὑψώσεως τῷ χρυσοῦ, that is, on the weighing of gold; extant in MS. Greek, in the king's library at Paris, and that of Fabricius at Hamburg.

72. ——— Divers chemical chapters; extant in MS. Greek, in the Vienna library, Cod. LI. and LII. n. 16.

73. ——— Labyrinth of Solomon, on tempering iron, making crystal, and other secrets of nature; extant in MS. Greek, in the Ambrosian library at Milan.

74. ΣΤΕΦΑΝΟΥ, Ἀλεξανδρείας, οὐκ ἐπιστολὴ φιλοσόφου, καὶ διδασκαλία τῆς μεγάλης καὶ ἱερᾶς τέχνης περὶ χρυσοποιίας, περὶ ἑνὸς ἑκάστου, περὶ ἩΡΑΚΛΕΙΟΝ τὸν βασιλέα; that is, *Stephen of Alexandria*, the universal philosopher and master, his nine processes on the great and sacred art of making gold and silver, addressed to the emperor *Heraclius*; extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 1. and in the library of Wolfenbützel.

75. ——— In Greek, in the king's library at Paris, the university library of Leyden, the Elizabeth library at Breslaw, the library of Gotha, the Ambrosian library at Milan, and in that of Fabricius at Hamburg.

76. ——— In Latin, translated by Dominicus Pizimentus; published together with Democritus de arte magna, and the pieces of Synesius, Pelagius, and Mich. Psellus on the same subject, at Padua 1573. 8vo.

77. ——— ἐπιστολὴ πρὸς ΘΕΟΔΩΡΟΝ, that is, an epistle to *Theodore*; extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and LII. n. 1. in the king's library at Paris, the Elizabeth library at Breslaw, the Ambrosian at Milan, and in that of Fabricius at Hamburg.

78. ΣΤΕΦΑΝΟΣ ὁ φιλόσοφος, that is, *Stephen the philosopher*; extant in MS. in Greek, in the electoral library at Munich.

79. ΠΑΠΠΟΥ φιλοσόφου ἔργον περὶ τῆς ἱερᾶς τέχνης, that is, *Pappus the philosopher's* work on the sacred art; extant in MS. Greek and Latin, in the Vienna library, Cod. LI. and

L. II. n. 25. In Greek, in the king's library at Paris, the Ambrosian library at Milan, the Elizabeth library at Breslaw, the library of Gotha, and that of Fabricius at Hamburg †.

80. ΑΡΙΣΤΟΤΕΛΕΣ, that is, *Aristotle* extant in MS. in Greek, in the library of the Escorial, and in that of the duke of Bavaria at Munich.

81. ——— de perfecto magisterio; extant in Guil. Gratarolus's collectio secretorum alchemizæ, edit. Basil. 1561. fol. p. 168. and T. II. edit. Basil. 1572. 8vo. also in the theatrum chemicum, Ursellus 1602. and Argent. 1613. 8vo. Tom. III. p. 56—118. and in Manget's Biblioth. Chem. T. 1. p. 638.

82. ——— Practica philosophici lapidis, published among the opuscula vet. philosophorum de alchemia. Francof. 1550. 4to. also in the theatrum chym. Argent. 1622. 8vo. Tom. V. and in Manget's Biblioth. Chym. T. I. p. 659.

83. ——— Breviarium, in MS. in the Bodleyan library.

84. ΜΙΧΑΗΛ ΨΕΛΛΟΣ περὶ χρυσοποιίας, that is, *Michael Psellus* on the art of making gold and silver, to Mich. Cerularius, patriarch of Constantinople; extant in MS. in Greek, in the Bodleyan library, being part of the donation of Mr. Selden; also in the library of the Escorial, and in that of the elector of Bavaria at Munich. Published also in Latin, translated by Dominic Pizamentius, together with Democritus, Synesius, Pelagius, and Stephanus Alexandrinus de magna & sacra arte. Patav. 1573. 8vo. ||

85. Τὸ μακαρίτη καὶ πανσόφῳ ΨΕΛΛΟΥ ἐπιστολὴ πρὸς τοὺς ἀγιώτατον πατριάρχην τοῦ ΕΠΙΦΑΝΙΝΟΝ περὶ χρυσοποιίας, that is, the blessed and universally learned *Psellus*, his epistle to the most holy patriarch *Xiphilin*, on the making of gold; extant in MS. in Greek, in the king's library at Paris, in the library of Gotha, and that of Fabricius at Hamburg.

86. Μέθοδος δι' ἧς ἀποτελεῖται ἡ σφαιροειδὴς χάραξ, κατασκευασθεῖσα παρὰ τῷ ἐκ τῆς τέχνης διὰ βούτῃ τῷ ΣΑΛΜΑΝᾷ, that is, the method of preparing round hail, as performed by the famous operator *Salmans*; extant in MS. in Greek, in the king's library at Paris, and in that of Fabricius at Hamburg.

87. ΝΙΚΗΦΟΡΟΥ τῷ ΒΛΗΜΜΗΔΟΥ, περὶ τῶν φυσικῶν ἀρχῶν, that is, *Nicephorus Blemmida* of physical principles §.

88. ΒΛΗΜΜΙΔΑΣ περὶ χρυσοποιίας, that is, *Blemmidas* on chrysopoeia, or the art

* In the VIIth century after Christ.

† In the XIth century after Christ.

† In the VIIth century after Christ.

§ In the XIIth century after Christ.

17. Concerning these Greek writers on alchemy see *Andreas Libavius*, thro' all his works, especially against *Guibert*; *Conringius de Med. Herm.* (c); *Borrichius de Ort. Chem.* (d), and against *Conringius* (e); *Fabricius Biblioth. gr. passim*, and the catalogue of the library of the university of *Leyden* (f).

18. One cannot easily forbear admiring to find that the excellent *G. Agricola* was well acquainted with these authors. In the preface to his elaborate treatise *de re metallica*, which was finished before the year 1550, and which is so applauded by *Erasmus*, he enumerates most of them, much in the order wherein they are above cited (g).

19. All these abovementioned authors, by chemistry only denote the art of converting the more imperfect metals into pure gold; nor appear to have ever thought of any thing like an universal medicine for all diseases of the human body (b). Signification of alchemy.

art of making gold; extant in MS. in Greek, in the king's library at Paris.

89. — *ἡγερον χημειν*, that is, chemical work; in MS. in Greek, in the library of the Escorial.

These pieces of Greek chemistry seem, by their antiquity and specious titles, to have greatly propagated the notion and practice of alchemy, or the search after the philosopher's stone; but there are grounds to suspect that they are chiefly fragments, and composed by monks and other men of letters, living at *Athens*, *Alexandria*, and *Constantinople*, long after the times of Christianity; then collected into a body, and brought into *Italy*, &c. probably by the refugee Greeks, after the siege of *Constantinople*. The collector is said to have lived after the reign of *Heraclius*, and to have interpolated and alter'd his collection at pleasure; so that scarce any thing can be gather'd from it concerning the age or religion, of these authors. *Reinesius* has given a learned censure of this body of Greek chemists in *High-Dutch*, which *Fabricius* gives us in *Latin*. Indeed, as *Herodotus*, *Clemens*, *Alexandrinus*, and other ancient writers, when they speak of the learning of the *Egyptians*, are silent as to the chemical art; and as *Pliny* says not a word of it, we rather agree with *Conringius* and *Reinesius*, than with *Borrichius*, that all the pieces extant in this collection of Greek manuscripts, under the names of *Hermes*, *Democritus*, *Aristotle*, &c. are at least posterior to the times of *Dioclesian* and *Theodosius*. None of them are publish'd in the ori-

ginal Greek; tho' several in *Latin*, and some in *English* translations†.

(c) P. 21. ad 31.

(d) P. 97.

(e) P. 66. ad 95.

(f) The author adds, in our former edition, "that the art seem'd now confin'd to the Greeks; and among them few wrote but the religious; who, from their solitary way of life, were led into vain enthusiastical speculations, to the great disservice and adulteration of the art. The greater part of them are yet in manuscript, and like to continue so, till chemistry is more studied, or the chemists know more Greek. They are all wrote in the natural style of the schoolmen, full of jargon, flights, and obscurity."

(g) *Χημεινὰ scripta Ὀψθανῆ, Hermes, Chanes, Zosimus Alexandrinus, ad sororem Theopsebam, Olympiodorus item Alexandrinus, Agathodæmon, Democritus, non Abderites ille, sed alius nescio qui, Orus Chrysorichites, Pebichius, Comerius, Johannes Apuleius, Petasius, Pelagius, Africanus, Theophilus, Synesius, Stephanus ad Heracleum Cæsarem, Heliodorus ad Theodosium, Geberus, Calides Rachaidibus, Verradianus, Rhodanus, Canides Merlinus, Raimundus Lullius, Arnoldus Villanovus, Augustinus Pantheus Venetus; scæmæ tres, Cleopatra, Virgo Taphnutia, Maria Judaica; bi omnes soluta oratione, unus Johannes Aurelius Augurellus Ariminensis versu scriptus*||.

(b) Vide *Conrig. de Med. Herm.* p. 15, 16. Improvers of Chemistry.

The origin of chemistry thus laid, we proceed

* *Bibl. Gr. L. 6. c. 8. p. 748, &c.*

† See *Theat. Chym. Turb. Philosophor. Aur. Vell. &c.* See also the philosophic works of *Hermes*, *Geber*, *Artephius*, *Flammel*, *Bacon*, and *Ripley*, english'd, with a comment on the first book of *Hermes*, by *W. Salmon*, 8vo. 1692.

|| See *Agric. de Re Metal. Præf.*

Origin of chemical physic
from mistakes.

20. But after the *Arabs* had begun to cultivate the art of chemistry hitherto spoke of, viz. as including metallurgy and alchemy; the metaphorical and hieroglyphical manner of writing, which obtained among them, seems to have given rise to a practice of calling the means or helps made use of for bringing metals to perfection, by the name of medicines; the imperfect metals, by the name of sick men; and gold, by that of a sound, lively, healthy, durable man. From whence the ignorant at length fell into the error of supposing that these were to be understood in a literal sense; especially upon finding the impurities of the baser metals, call'd by the name of leprosy, the most incurable of all diseases. Hence, first, rose an opinion, which has since been propagated far and wide, that the imperfect metals might be transmuted into gold, and the bodies of sick men into sound ones, by one and the same chemical preparation: to which they gave the name of the philosopher's stone, or the gift *azoth*; and call'd its possessors *adepts*. The opinion seem'd confirm'd from a few simple experiments of extracting medicinal virtues from drugs by chemistry; which *Rhazes* had given the first instances of, but which in the eleventh century *Avicenna* (i) further illustrated, in a description of the *Arabian Julab*, or distilled rose-water, and *Mesue* afterwards confirmed more at large.

Writers on
alchemy since
the Greeks.
800.
viz. Geber.

21. The chief among these Authors were the following; viz. (1) *Geber*, call'd the *Arab*, but really a *Greek* by country, according to *Leo Africanus*; having first been a Christian, but afterwards turn'd Mahometan. He liv'd in the seventh century, and writ in *Arabic* (k). His works were translated into Latin

ceed to relate the progress thereof; and who the principal authors were that contributed to its advancement, as well as those who corrupted it: at the same time noting their several writings, the best editions, and the order wherein they are to be read.

And here we judge it proper to distinguish the chemists into three classes; either as they treat of metals, of alchemy, or medicine.

(i) See his treatise on the power of the heart.

(k) Account of Geber.

1. "This author appears to have been the first great reformer and improver of chemistry. His history is very obscure: the name *Geber* signifies a great man, and a king; whence he is commonly supposed to have been a prince; and as he wrote in *Arabic*, a prince of *Arabia*. But neither the person nor the time he lived in, is known with any tolerable certainty.

2. "He is supposed to have given the first handle to an enquiry after an universal medicine; there being some expressions in his book, which might easily enough lead an unwary reader to think he was acquainted therewith. As, *Gold thus prepared cures lepra's, cures all diseases, &c.* But we are

"here to observe, that in his language, the baser metals are all leproous men, and gold a healthy one. When therefore he says, *I will cure six lepers*, he means no more than that he will turn them into gold, which shall bear the trial of antimony. But as he was no physician, 'tis more than probable he never thought of any universal remedy. After this writer we don't meet with any other of distinction till the twelfth century.

3. "*Goli*, professor of the oriental languages in the university of *Leiden*, made the first present of *Geber's* piece, in manuscript, to the publick library; and translated it into *Latin*, and published it in the same city, in *folio*; and afterwards in *quarto*, under the title of *Lapis Philosophorum*. It contains abundance of curious and useful things about the nature of metals, their purification, fusion, malleability, &c. with excellent accounts of salts, and *aqua fortis*. Several of his experiments are verified by present practice, and have passed for modern discoveries: the exactness of his operations is really surprizing, except perhaps in what relates to the philosopher's stone."

Latin by several hands, and published by Golius (1). The chief of his pieces were these:

1. *De alchemia, vel chymia; aut de investigatione perfectionis metallorum*: that is, of alchemy, of chemistry; or of discovering the perfection of metals.
2. *De summa perfectione metallorum*: that is, of the highest perfection of metals.
3. *De claritate alchimie*: that is, of the excellence of alchemy.
4. *De Lapide philosophico*: that is, of the philosopher's-stone.
5. *De testamento*: that is, of the testament.
6. *De epitaphio*: that is, of the epitaph.
7. *De inveniendâ arte auri & argenti*: that is, of finding the art of making gold and silver (m).

22. (2) *Morienus*, a Roman, who lived as a hermit at Jerusalem, wrote very soberly on this secret, and is rank'd amongst the purest authors extant: his works were translated out of Arabic into Latin, and publish'd in the year 1182, on the eleventh day of February (n).

23. (3) *Albertus Bolstadius*, surnamed *Grotus*, or *Magnus* (o), a German, born at Magnus.

E 2

(1) *Vid. Leo. Afr. L. III. p. 136. Conring. Herm. Med. 369, 372, 373.*

His Writings.

(m) To which may be added, 1. *Geberi super artem Alchimie Libri vi.* or Geber's six books on the art of alchemy; extant in MS. Membr. 4to. in the Bodleian library; part of the donation of *Elias Ashmole Esq;*

2. *De Alchimia Libri iii.* that is, three books on alchemy, publish'd Argent. 1529. folio.

3. *Geberis summa perfectionis magisterii in sua natura*: that is, the height of perfection of the magistrery, in its own nature: very incorrectly printed from a correct copy in the Vatican library, with the addition of some chapters, vessels, and furnaces, omitted in the other; besides Geber's books of the investigation of the magistrery, of the testament, the golden book, *trium verborum*, and *Avicenna*, on minerals, Venet. 1542. 8vo. ap. Petr. Schoeffer. c. Fig. — Norib. 1545. 4to. c. Fig. — Arg. 1598. 8vo.

4. *Chymia, seu traditio summa perfectionis, & investigatio magisterii*: that is, chemistry, or the tradition of the highest perfection, and the investigation of the magistrery; corrected in innumerable places by *Casp. Hornius*: to which is added, the same authors *Medulla Alchimie Gebrie*. The whole published by G. Hornius. Lug. Bat. 1669. 12mo.

The works of Geber are also published in English, by Richard Russell. London 1686. 8vo.

Avicenna's Chemical Writings.

In the next place might come *Avicenna*, who lived in the eleventh century; and who, as his follower *Soranus* informs us, wrote a

book on alchemy; but there are more chemical pieces that go under his name, viz.

1. *Abobali, i. e. Avicenna liber de rebus alchymicis*: i. e. *Abobali's*, or *Avicenna's* book on the subject of alchemy; extant in MS. in the Bodleian library, given by Sir *Kenelm Digby*; besides another copy given by *Elias Ashmole Esq;*

2. *Tractatus de tinctura metallorum*. A treatise of the tincture of metals; publish'd at Franckfort 1550. 4to.

3. *Chemicus liber, porta elementorum dictus*: Chemical book, called the gate of the elements. Basil. 1572. 8vo.

4. *Mineralia, seu de congelatione & conglutinatione lapidum*: that is, minerals, or on the congelation and conglutination of stones. Publish'd with Geber's *Summa perfectionis magisterii in sua natura*, and other pieces on the same subject. Venet. 1542. 8vo. Also in the *Theatr. Chym. T. IV. p. 936.* and in *Manger's Bibl. Chym. T. 1. p. 636.*

Morienus's Writings.

(n) Add to this, 1. *Liber de compositione alchemie*; or, a book on the composition of alchemy. Extant in *Manger's Bibl. Chym. T. 1. p. 509.*

2. *Liber de distinctione mercurii aquarum*: or a book on the distinction of the mercury of waters; found in MS. in the Bodleian library; given by *El. Ashmole Esq;*

Account of Albertus Magnus, and his writings.

(o) *Albertus Magnus*, now known by upwards of 20 volumes in folio, is said to have been first distinguish'd by his dulness and stupidity; inasmuch that he became the common

1182.

1200.

at *Lavingben* in *Suabia* about 1200, in 1259 preferred to the bishopric of *Ratisbon*, and died in 1280: He wrote,

1. *De mineralibus*: or, a Book of minerals (p).
2. *Lilium floris de spinis avulsum*: that is, the lilly of the flower pluck'd from the prickles.
3. *Speculum alchemiæ de compositione lapidis*, &c. that is, the mirror of alchemy, concerning the composition of the stone (q).

Friar Bacon.

24. (4) *Roger Bacon*, an *Englishman*, a monk of *Westminster*, but residing at *Oxford*, where he flourished about the year 1226; excelled in alchemy, chemistry, natural magic, mechanics, metaphysics, physics, and mathematics. He died at *Oxford* in 1284, and was buried there among the *Franciscans* (r). Such of his works as have been handed down to us, are generally

mon jest of his fellow-students. At length quite tired out, he resolved to scale the walls of the convent, and run away. In this attempt, the blessed Virgin appear'd to him on the wall, and there gave him that understanding and ability, which have since render'd him so famous. He was a *Dominican* friar, and doctor of *Paris*; flourish'd in 1236, and taught at *Cologne*, where he had *Thomas Aquinas* for his pupil. He retired from his bishopric to his monastery at *Cologne* in 1263, and died in 1280, aged seventy-five. Father *L'Abbé* says, in his eloge, that he wrote sixty volumes, most of them still extant, many in print, the rest in MS. *Petr. Jammy* has publish'd an edition of his works, but not all, in twenty-one volumes, fol. *Lugdun.* 1651. The list of titles in each volume is given by *Fabricius*, p. 113, &c. He was accused of magic, but is defended by *Tritheimius*, *Mirandula*, *Naudé*, and others. By a general correspondence with the miners throughout Germany, he acquired uncommon skill in metallurgy. The feast of the beautified *Albertus* is celebrated in the churches of *Ratisbon* and *Cologne*.

(p) *De mineralibus & rebus metallicis*, Lib. v. *Oppenbemi*, 1518. 4to. that is, of minerals and metallic matters, five books, &c. corrected and republished by *Gualib. Herm. Argent.* 1541. 8vo. And again in the *Theatr. Chym.* T. II. p. 139. There is also a small piece of his upon alchemy, entitled *de Alchemia libellus*; printed at *Basil* in 1516.

(q) See *Borell. Biblioth. Chym.* p. 5.

Next after *Albertus* might come *Thomas de Aquina*, a *Dominican*, born, of the noble family of the counts of *Aquina*, in 1234. He died in his journey to the second council of *Lyons*, whither he had been summon'd by Pope *Urban IV.* in the monastery of *Fossa Nuova*, not far from *Terracina*, in 1274. His chemical writings are,

1. *Secreta alchemiæ magnalia, de corporibus supercalculis, & quod in rebus inferioribus inveniuntur, quoque modo extrahantur*: or capital secrets of alchemy, concerning the supercelestial bodies; and to shew that they are found in sublunary bodies, and how they may be extracted from the same.

2. *De lapide minerali, animali, & plantali*; or, of the mineral, animal, and vegetable stone.

3. *Thesaurus alchemiæ secretissimus, quem dedit fratri suo Reinaldo*: or, the most secret treasure of alchemy, given to his brother *Reinaldo*.—To which are added *Joban. de Rupe-scissa's* book of light; and *Raym. Lully's Clavicula & Apertorium*, publish'd by *Dan. Bronchusius*, with a preface by *Job. Heurnius. Lug. Bat.* 1598. 8vo. And in the *Theatr. Chym.* T. III. p. 277.

4. *Liber lilii benedicti*: or, a book of the blessed lilly. Extant in *Theatr. Chym.* T. IV. p. 1082.

5. *Aurora, sive aurea hora*: the dawn, or the golden hour.

6. *Commentarium super turbam philosophorum breviorum, ut dicitur*: or, a commentary on the shorter *turma philosophorum*. Extant in the second *decad* of the *Harmon. chym. philosophica*, collected by *Jos. Rhenanus. Francof.* 1625. 8vo.

Account of Friar Bacon.

(r) "1. He was beyond all comparison the greatest man of his time; and might perhaps stand in competition with the greatest that have appear'd since. 'Tis wonderful, considering the ignorant age wherein he lived, how he came by such a depth of knowledge on all subjects. His writings are composed with that elegancy, conciseness, and strength, and abound with such just and exquisite observations on nature, that, among all the chemists, we don't know his equal.

"2.

rally written in a clear, easy style, without circumlocutions. We have the following pieces of his writing.

" 2. He writ many treatises, some of which are lost, or lock'd up in private libraries. What relate to chemistry, are chiefly two small pieces wrote at Oxford, which are now in print, and the manuscripts to be seen in the public library of Leyden; having been carried thither among Vossius's manuscripts from England. In these he attempts to shew how imperfect metals may be ripen'd into perfect ones. He adopts Geber's notion, that mercury is the common basis of all metals, and sulphur the cement; and shews, that it is by a gradual depuration of the mercurial matter, and the accession of a subtile sulphur, that nature produces gold; and that if, during the process, any other third matter happens to intervene, beside the mercury and sulphur, some other baser metal will arise, so that if we could but imitate nature's method, we might change other metals into gold.

" 3. Having compared several of Friar Bacon's operations with the modern experiments of M. Homberg, made by direction of that curious prince, the duke of Orleans; we judge that Bacon has describ'd some of the very things which Homberg publishes as new discoveries. Thus, for instance, Bacon teaches expressly, that if a pure sulphur be united with mercury, it will produce gold: on which very principle M. Homberg has made many experiments for the production of gold, described in the *Memoires de l'Academie Royale des Sciences* *.

" 4. His other physical writings shew no less genius and force of mind. In his treatise, of the secret works of art and nature, he shews, that a person, who was perfectly

" acquainted with the manner which nature observes in her operations, would not only be able to rival, but surpass her. In another piece, of the nullity of magic, he shews, with great sagacity and penetration, whence the notion sprang, and how weak all pretensions to it are. Admiration, the parent of magic, is the offspring of ignorance, begot upon a vitiated imagination: when weak minds perceive an effect, whose cause is hid far in the dark, they presently have recourse to a daemon to solve the difficulty; for they fancy, it must be the effect of magical art, or the intervention of some supernatural power. This popular refuge of ignorance the judicious author deservedly confutes, and shews there is no such thing as magic; unless by that word he meant a knowledge of the properties of bodies, and the methods of nature; by a dextrous application whereof many things may be produced more surprizing than all the pretended magic has ever effected.

" 5. Such was the scope and tendency of his writings. What reward he met with is abominable to say: the man who had thus overthrown the idle pretensions of the believers in magic, was himself branded for a magician, excommunicated, and imprisoned.

" 6. His works are printed in 8vo and 12mo; under the title of, *Frater Rogerius Baco de secretis artis & naturæ*, and in folio at London. From a repeated perusal of them, we find our friar was no stranger to many of the capital discoveries of the present and past ages.

" 7. Gun-powder he certainly knew: thunder

* 1. M. Homberg, in his *Essai du souffre principe*, gives us two experiments; the first with mercury, which upon being exposed to a digesting heat, ceases to be fluid, becomes a powder heavier than mercury, and at length acquires such a fixedness, as to be capable of remaining red-hot for twenty-four hours, without loss; tho' upon applying a naked fire, the greatest part flies off in fume, leaving a piece of hard metal, form'd of the mercury, behind. The other experiment is with *regulus* of antimony, which, upon being exposed to the duke of Orleans's great burning-glass to calcine, gained one tenth part in weight. From these experiments he concludes, that light may be introduced into porous bodies, may there fix, and increase both their weight and bulk: and that the light thus retain'd in mercury, becomes inseparable therefrom in the most vehement fire; and even changes the form of the mercury into a malleable ductile metal, heavier than any other metal, except gold. *Mem. de l'Acad. An. 1705.*

2. In another place the same author argues, that gold consists principally of two kinds of matter, viz. mercury or quicksilver, and a metallic sulphur; the latter, according to him, being no other than light; either of which taken apart, evaporates with the least heat; but when join'd together into a metal, after the manner just mention'd, they lose their volatility, and become so fixed, that the most intense fire of our laboratories cannot separate them. *Mem. de l'Acad. An. 1707.*

The History of CHEMISTRY.

1. *Speculum alchemiæ*; or the mirror of alchemy (*s*); and another different from the printed one, which is preserved in MS. in the library of *Leyden*.
2. *Theſaurum chemicum*; or, the treasure of chemistry.
3. *De ſecretis artis, atque naturæ operibus*; or, of the ſecret works of nature and art.
4. *De nullitate magiæ*; or, of the nullity of magic (*t*).
5. *Scripta de arte chemiæ*; or, writings on the art of chemistry; publiſh'd at *Frankfort* in 12°. 1603. (*u*) wherein (*x*) we find many elegant diſcoveries in mechanics,

“ der and lightning, he tells us, may be produced by art; for that ſulphur, nitre, and charcoal, which, when ſeparate, have no ſenſible effect, yet when mixed together in a due proportion, and cloſely confin'd and fired, they yield a loud report. A more precise deſcription of gun-powder cannot be given in words: and yet a Jeſuit, *Barthol. Schwartz*, ſome ages after, has had the glory of the diſcovery. He likewiſe mentions a ſort of inextinguiſhable fire, prepared by art: which ſhews he was not unacquainted with phoſphorus. And that he had a notion of the rarification of the air, and the ſtructure of an air pump, is paſt contradiction.”

See farther concerning the life and writings of this extraordinary perſon, *Wood's Athen. Oxon.* p. 136, &c. *Wadding*, in *Annal. Ord. Minor. ad Ann.* 1266. and 1278. *Leland de Scriptor.* c. 236, *Bayle's Diſſ.* *Fabric. Biblioth. Med. Lat.* l. 2. p. 430, &c.

(*s*) Extant in *Gratarolus's* collection of writers *de vera alchemia*. *Baſil.* fol. *A D.* 1561.

(*t*) Extant in the *Theatr. Chym.* T. II. p. 433. and in *Manges. Biblioth. Chym.* T. I. p. 613, and 616.

(*u*) To theſe are tack'd ſeveral pieces of the ſame author, *viz.*

Breviarium de dono dei.

Verbum abbreviatum de leone viridi; and *Secretum ſecretorum naturæ, de laude lapidis philoſophorum.*

(*x*) This character ſeems rather to belong to the *Speculum ſecretorum* of *Friar Bacon*, or this mirror of ſecrets; printed at *Frankfort*, in 12mo, by *J. T. Schenkwetter*, An. 1603.

We think proper here to ſubjoin a catalogue of this great man's writings, ſo far as they are come to our knowledge, having ſome reaſon to ſuſpect that ſeveral of his works are ſtill unpubliſh'd.

A Catalogue of Friar Bacon's Writings.

1. *Traſtatus duo de chemia.*
2. *Speculum alchemiæ.*
3. *Theſaurum chymicum.*
4. *De ſecretis artis atque naturæ operibus, & de nullitate magiæ.*
5. *Specula mathematica.*
6. *Medulla alchemiæ*, in 8vo. An. 1608.
7. *De arte chemia ſcripta.*
8. *Breviarium de dono dei.*
9. *Verbum abbreviatum de leone viridi.*
10. *Secretum ſecretorum naturæ de laude lapidis philoſophorum.*
11. *Traſtatus trium verborum.*
12. *Epistoſa de modo miſcendi.*
13. *Epistoſa ſecretiſſima de ponderibus.*
14. *Speculum ſecretorum.*
15. *Opus majus, ad Clem. IV.*

16. *Rog. Baconis epistoſa de ſecretis operibus artis & naturæ, & de nullitate magiæ. Opera Joh. Dee. Londin. & pluribus exemplaribus caſtigata olim, & ad ſenſum integrum reſtituta. Nunc vero à quodam veritatis amatori in gratiam*

1. Two treatiſes of chemistry.
2. Mirror of alchemy.
3. Chemical treaſure.
4. Of the ſecret works of art and nature, and the non-entity of magic.
5. Mathematical mirrors.
6. Marrow of alchemy.
7. Writings upon the art of chemistry.
8. Breviary of God's gift.
9. A word of the green lion.
10. Secret of nature's ſecrets; in praife of the philoſopher's ſtone.
11. Treatiſe of three words.
12. Epistle of the manner of mixings.
13. A ſecret epistle of weights.
14. Mirror of ſecrets.
15. Great work, addreſſed to Pope *Clement IV.* found in the library of *Dublin*, and lately publiſh'd by *Dr. Jebb*, in folio.

16. *Roger Bacon's* epistles on the ſecret works of art and nature, and the non-exiſtence of magic, by *Joh. Dee* of *London*; formerly compared with numerous copies, and reſtored to the true ſenſe, and now publiſh'd by a lover

mechanics, natural magic, and other arts which have been falsely attributed to later authors; and were no less falsely charged on him as the effect of magic and hereby (y).

25. (5) *George Ripley*, likewise an *Englishman*, and Canon of *Bridlington*, 1477. flourished much about the same time (z). He wrote,

1. *Duodecim portæ*: or, the twelve gates (a).

2. *Medulla chimica*: or, the marrow of chemistry.

3. A piece on alchemy compos'd in *English* verse, and now preserv'd in MS. in the library of *Leyden*. His works were published together at *Cassel*, in 8°. 1649 (b).

See also *de mercurio philosophorum*; or, a piece on the mercury of the philosophers; and *commentarium Hermæsi philosophi*, now in MS. in the library of *Leyden*.

26. (6) *Arnoldus de Villa nova* lived in the thirteenth century (c,) and wrote, 1300. *Arnoldus de Villa Nova*.

1. *Rosarium*. The Rosary.

tiam vera scientia emissa, cum notis quibusdam partim ipsius Job. Dee, partim edentis. Cum responsione ad fratres Rosacea crucis illustres. Hamb. 1618. 8vo.

lover of the truth, for the improvement of real knowledge; with notes, partly by the said *John Dee*, and partly by the editor; and an answer to the illustrious brothers of the *Rosercrucian* order. *Hamburg* 1618. 8vo.

(y) See *Barriach. de Ort. Chem.* p. 122. and *Borell. Bihl.* p. 37.

Account of Ripley.

(z) "This author lived in the reign of *Edward IV.*, to whom, an. 1577, he dedicated his book, entitled, *The twelve gates*. "His writings are all very good in their kind, being wrote in *Bacon's* manner, only more allegorical. As he was no physician, he does not meddle with any thing of the preparations of that kind; but treats much of the cure of *metals*, which, in his language, is the purification and maturation thereof. He pursued *Geber's* and *Bacon's* principles very religiously; and maintain'd, for instance, with new evidence, that mercury is the universal matter of all metals; that this, exposed to the fire with the purest sulphur, will become gold; but that if either of them be sick or leprous, that is, infected with any impurity, instead of gold, some other metal will be produced. He adds, that as mercury and sulphur are sufficient for the making of all metals; so of these may an universal medicine, or universal metal, be produced, for curing of all the sick; which some have inadvertently understood of an universal medicine, efficacious in all diseases." 'Tis said, that *Ripley* sent an hundred thousand pounds, for several years successively, to the knights of *Rhodes*, to enable them to defend themselves against the *Turks* *.

* See *Nouv. de la Repub. des Let.* 1708. p. 199.

(a) *Duodecim portæ axiomatum in philosoph.* or, twelve gates of philosophical axioms.

(b) To which may be added,

1. *Pupilla oculi*, the pupil of the eye, with a preface, preserved in MS. in the *Bodleian* library, given by *Elias Ashmole* Esq;

2. *De regimine ignium philosophorum & quibusdam probatissimis experimentis*; viz. of the management of the fires of the philosophers, together with some approved experiments; found in MS. in the *Bodleian* library, part of the donation of the same person.

For a farther account of this author's writings, see *Fabric.* l. 7. p. 104.

Account of Arnoldus de Villa Nova.

(c) This author was a *Frenchman*, and denominated *Arnaud de Ville Neuve*, from *Ville Neuve*, the place of his nativity. He was a celebrated philosopher, physician, and chemist; and thought to be deeply skill'd in alchemy. *Van Helmont*, a great admirer of *Arnaud*, attributes to him the first introducing of chemistry into medicine. He was sent by *Frederick*, king of *Sicily*, to cure *Pope Clement V*; but being shipwreck'd in the voyage, died in 1313, and was buried at *Genoa*. The *Spaniards* maintain he was a *Catalan*; 'tis certain he practis'd physic at *Barcelona*, whence he acquir'd the surname *Catalanus*. He was suspected of magic. But for his fate and writings, see *Nicbol. Anton. Biblioth. Ves. Hispan. L. IX. c. 1. T. II. p. 74. &c.* and *Fabric. Bibl. Med. Latin. l. 1. p. 358.*

The History of CHEMISTRY.

2. *Testamentum novum practicum.* A new practical testament.
3. *De Alchemia.* On alchemy. And
4. *Semita Semitarum.* The path of paths.

To these may be added,

1. *Rosa novella.* The new Rose.
2. *Epistola ad papam Pium.* An Epistle to Pope Pius,
3. *Novus splendor, vel lumen.* A new light, or brightness.
4. *Flos florum.* The flower of flowers.
5. *De furno philosophico.* On the philosophical furnace.
6. *De secretis naturæ.* Of the secrets of nature.
7. *De nova compositione lapidis vitæ philosophorum.* Of a new composition of the stone of life of the philosophers.
8. *De principiis naturalibus, ad Clementem papam.* Of natural principles to Pope Clement
9. *Opus in arte majore.* A work on the grand art: which pieces are all in MS. in the library of Leyden (d).

1235.
Raymond
Lully.

27. (7) *Raymund Lully*, a Spaniard, born at *Barcelona* (e) in the year 1235, a disciple of *Arnoldus de Villa nova*, died in *Africa* in 1315. He was one of the

His writings.

(d) Besides these we have of his writings,
10. *Speculum alchemiæ, quo artis chemicæ mysteria, etiam secretissima, luculenter enodantur & explicantur.* The mirror of alchemy, wherein the most secret mysteries of the chemical art, are clearly unfolded: first publish'd by *Jer. Magisterus*. *Francos.* 1602. 8vo. Afterwards, together with his other chemical writings, by the same editor. *Francos.* 1603. 8vo.

11. *Opera, una cum ipsius vitæ, a Symphor. Campegio descripta; ac tractatus de lapide philosophorum.* His works, together with his life, written by *Symphor. Campegius*; to which is added, a tract on the philosopher's stone. *Lugd.* 1530. 8vo.

12. *Opera, cum Nic. Tawcelli annotationibus.* Works, with the annotations of *Nic. Tawcellus*. *Baf.* 1585. folio.

13. *Theaurus thesaurorum.* The treasure of treasures, preserved in MS. in the Bodleian library, part of the donation of *El. Asmole Esq;*

14. *Tract. de solutione dubiorum in alchemia.* Or, of the solution of doubts in alchemy: in MS. extant in the same library, given by *Sir Kenelm Digby*.

Account of Raymond Lully.

(e) " 1. This author is said by others to " have been born in *Majorca*, and by some " in *Minorca*, but sprung from the noble family of the *Lullies* in *Barcelona*. His contemporaries speak of him as a person eminently versed in the peripatetic learning; " which indeed appears from several of his " writings. He had the address to introduce

" a new kind of transcendental art called from " him the *Lullian* art: by virtue whereof a " man might dispute whole days upon any " topic in nature, without understanding any " thing of the matter. The drift of this doctrine was to dispose the several sorts of beings into divers climax's, or scales, to be run down in a descending progression. Thus, " whatever was proposed to be talk'd on " they would say, first it is a *being*; and consequently, *one*; *true*; *good*; then, every being is either *created*, or *uncreated*: and " every created being is either *body*, or *spirit*, " &c. But, at length, perceiving the vanity " of his own art, he quitted this barren superfluity of words, and went over to the " other extreme.

" 2. Upon applying himself to chemistry, he soon began to preach another sort of doctrine; for speaking of that art, " he says it is only to be acquired by experiment, and cannot be conveyed to the understanding by idle words and sounds.

" 3. *Lully*, besides what he did in the scholastic way, writ several volumes after changing his manner of study: 'tis difficult to say " how many; for it was a common practice " with his followers to publish their performances under their master's name. His " later works are, beyond all expectation, " excellent; so that it may be doubted, whether they were the production of that age. " So full are they of the experiments and observations which occur in our later writers, " that either the books must be supposititious, " or the ancient chemists must have been acquainted

the first who in his Treatise entitled *de quinta essentia*, wrote of an universal remedy for all diseases of the body, and of the philosopher's stone: his chief writings are,

1. *De secretis natura, seu quinta essentia*. Of the secrets of nature, or the quintessence.

2. *De accurtatione lapidis philosophorum*. Of shortning the work of the philosopher's stone.

3. *Codicillum, seu vade mecum de formatione lapidum pretiosorum*. A codicil, or *vade mecum* of the making of precious stones: now in MS. in the library of Leyden (f).

4. *Clavicula de l. p.* Clavicle, or little key of the philosopher's stone.

5. *Testamentum*. The Testament.

6. *Apertorium*. An apertory.

7. *Epistola ad Edwardum regem Anglia*. Epistles to Edward king of England.

8. *Lux mercuriorum*. Light of mercuries.

9. *De mercurio*. Of mercury.

10. *Speculum magnum*. The great mirror.

11. *Testamentum novissimum*. The last testament.

12. *Epistola ad Robertum regem Anglia*. An epistle to Robert king of England (g).

13. *Aphorismi* Aphorisms.

14. *Epistola accurtationum*. An epistle of shortning proceses.

15. *De investigatione occulti secreti*. Of the discovery of the deep secret.

16. *Exempla accurtationis*. Instances of shortening.

All

" quainted with many things which pass for
" the discoveries of modern practice. He
" gives plain intimations of *phosphorus*, which
" he calls the *vestal fire*; the *essu Helmontii*,
" &c. And yet he must have lived two hun-
" dred years before either *Helmont* or Lord
" *Bacon*.

" 4. He travell'd into *Mauritania*, where
" he is supposed to have first met with che-
" mistry; and to have imbib'd his principles
" of the art from the writings of *Geber*:
" which opinion is countenanced by the con-
" formity observable between them.

" 5. The *Spanish* authors ascribe the occa-
" sion of his journey to a passion he had for a
" maid, named *Eleonora*, who obstinately re-
" fused his addresses. Upon enquiring into
" the reason, she shewed him a cancer'd breast,
" *Lully*, like a generous gallant, immediately
" resolves on a voyage to *Mauritania*, where
" *Gaber* had lived; to seek some relief for his
" mistress. But others say, that from thence-
" forward he devoted himself to penance; and
" among other pious exercises, applied him-

" self to the conversion of infidels, with a
" view to which he learn'd *Arabic* at thirty
" years of age. At his solicitation, *James*,
" king of *Arragon*, founded a seminary in *Ma-
" jorca*, for the education of missionaries. After
" which he travell'd thro' *France*, *Germany*,
" and *England*; and was at last stoned to
" death in *Africa*, for preaching christianity."

There are said to have been two *Raymund Lullies*, the one a friar and a martyr; the other an alchemist, and originally a Jew. 'Tis said there are above a hundred chemical MSS. of *Raymund Lully*, yet unpublisch'd, in the *Vienna* library*. But for more particulars relating to this adept, see *Vinc. Mutio's Historia del Regno de Mallorca; Dissertationes Historicas del Cultu immemorial de B. Raimundo Lullio*. Mail. 1700. 4to. *Memoir. de Trev.* Nov. 1701. p. 236. & seq. *Du Pin, Biblioth. Eccles.* T. XI. p. 60. and *Borrich. de Ori.* p. 133—139.

(f) And also published *Rottem.* 1651. 8vo.

(g) Perhaps it should be *Robert* king of *Sicily*†.

* See *Merhof. Polyhist.* L. I. c. 11. n. 56.

† See *Borrich. de Ori. Chm.* p. 137.

All which pieces are in MS. in the library of *Leyden*. He is even said to have written to the number of sixty volumes on chemical subjects (*b*).

1375.
Johannes de
Rupescissa.

28. (8) *Johannes de Rupescissa*, a Franciscan, died in prison, about the year 1375. He wrote many pieces on alchemy (*i*). *Paracelsus* censures him as having advanced things false and ridiculous (*k*).

1420.
Isaac Hollan-
dus, and John
Isaac Hollan-
dus.

29. (9) *Isaac Hollandus* and *John Isaac Hollandus*, born at *Stolk*, a village of *Holland*, wrote several pieces on alchemy, wherein they deliver many extraordinary experiments (*l*), viz.

1. *De lapide philosophorum*. Of the philosopher's stone (*m*).
2. *Scientia chimie*. The science of chemistry.
3. *De projectione infinita*. Of infinite projection.
4. *De mineralibus & vera metallorum metamorphosi*. Of minerals, and the true transmutation of metals (*n*).

(*b*) A fair copy of all *Lully's* chemical works, transcribed in 1483 and 1484, in two vol. fol. is preserved in the *Bodleian* library, given by *El. Ashmole Esq*; See also *Theatr. Chym.* T. III. and IV. and *Mangeti Bibl. Chym.* T. I.

(*i*) His writings are; 1. *Liber magisterii de confessione veri lapidis philosophorum*. The book of magistry on making the true philosopher's stone. Published with other pieces of alchemy. Collected by *Gratareolus*. *Bas.* 1561. fol. T. II. p. 126. In the *Theatr. Chym.* T. III. p. 191. and *Mangeti's Bibl. Chym.* T. III. p. 80.

2. *Liber lucis*; Book of light: published with the *Secreta alchimie magnalia* of *Tho. Aquinas*, by *Dan. Brouhuissus*. *Lug. Bat.* 1598. 8vo. In the *Theatr. Chym.* T. III. p. 297. And *Mangeti Bibl. Chym.* T. II. p. 84.

3. *Rosarium philosophorum*: the rosary of the philosophers; from a double copy. Extant in *Mangeti Bibl. Chym.* T. II. p. 87. and 119.

4. *De consideratione quintæ essentia rerum omnium*. Of the consideration of the quintessence of all things. *Bas.* 1597. 8vo*.

Account of *Johannes de Rupescissa*.

(*k*) "This author is held as the patriarch of the chemists: his writings are many, easy to be procured, and of great weight. Besides his theological pieces, he wrote many chemical ones; and had wrote more, as having a strong chemical taste, but that like his great predecessor *Bacon*, he was accused of magic, and thrown into prison; where he pined away, and died of grief; by which means he was prevented from discovering many secrets of nature, which he was become master of."

Account of *Isaac and John Hollandus*.

(*l*) "1. Some say these were father and son; others, that they were brothers: whether, is not easy to determine. But certain

5.
"it is, they were both persons of great parts and ingenuity, and wrote on the dry topics of chemistry, with all the copious eloquence of orators. They seem to have lived in the thirteenth century; but this is not assured. The whole art of enamelling is their invention; as is also that of colouring glass, and precious stones, by the application of thin metal plates thereon.

"2. Their writings are in the form of processes; and they describe all the operations to the most minute circumstances. The treatise of enamelling is esteem'd the greatest, and most finish'd part of their works; all that relates to the necessary fusion, separation, and preparation of the metals is here deliver'd. They write excellently of distillation, fermentation, putrefaction, and their effects; and seem to have understood, at least, as much of these matters as any of the moderns. They publish'd a small *Treatise of the philosopher's stone*; which, they hold, may be prepared from any body in nature. They describe ways of producing it from lead, blood, sulphur, and mercury, and other matters. They furnish several experiments on human blood; which *Van Helmont* and *Mr. Boyle* have since repeated. *Paracelsus* likewise has borrowed freely from them. There goes a very large work, in folio, under their name, of the construction of chemical furnaces and instruments."

(*m*) Extant in the *Theatr. Chym.* T. II. p. 142.

(*n*) *Opera mineralia, sive de lapide philosophorum*. Mineral works, or on the philosopher's stone. Extant in the *Theatr. Chym.* T. III. p. 320. Also published at *Middelb.* 1600. 8vo. *Opera mineralia & vegetabilia*. Mineral and vegetable works. *Arnhem.* 1616. 8vo.

* Vid. *Couring. Herm. Med.* p. 210, 383, & seq. and *Borell. Bibl. Chem.* p. 193.

5. *De vino.* Of wine.

6. *De vegetabilibus.* Of vegetables (o), with some others (p).

30. (10) *Basil Valentine* (q), is commonly said to have been a *Benedictine* monk at *Erfurt*; tho' we are inform'd there never was any *Benedictine* monastery at *Erfurt*; and both his Names seem apparently coin'd; the one from the *Greek*, the other from the *Latin*. He was perfectly skill'd in the vulgar chemistry, as may appear from his single piece entitled *Currus triumphalis antimonii*: or, triumphal chariot of antimony; wherein many of the chemical processes accounted modern, are accurately comprized, and faithfully described. Nor was he less eminent in the more abstruse part of the art: his chief failing was the ascribing medicinal virtues to every thing procured from antimony; than which nothing can be more absurd, fallacious, or pernicious. Yet the same fatal error has hence infected all the tribe of chemists to this day. He also shews himself to have been both a divine and a physician; and seems likewise to have been famous in the courts of princes. He is supposed to have lived an age earlier than *Paracelsus*; and was the first that broach'd the doctrine of the three chemical principles; from whence *Paracelsus* borrowed many

Authors in the medicinal part of chemistry. 1490. Basil Valentine.

F 2

(o) *Opera vegetabilia*: vegetable works. *Francof.* 1666. 8vo.

(p) Besides the pieces above enumerated, they also wrote;

1. *Manus philosophica*; the philosophical guide.

2. *De salibus & oleis metallorum.* Of the salts and oils of metals.

Translation of chemistry to medicine.

"All the authors hitherto rehearsed have been chiefly confined to metallurgy, or a few particular bodies, as metals, glass, artificial gems, &c. about which all the chemists from *Zosimus* to *Hollandus* seem to have been employ'd. We now proceed to the second class of chemists; viz. those who have cultivated the art with a view to medicine; whether in order to find an universal remedy, or particular ones, in the common way of physie. *Basil Valentine* is the first of this list." But the learned *M. le Clerc* thinks there are also indications of chemical medicines in *Thaddæus the Florentine*, who lived in the thirteenth century, in *Albertus Magnus*, *Arnoldus de Villa Nova*, *Lully*, *Friar Bacon*, and *Isaac Hollandus* †. And here it is very remarkable what *Guainerus*, who lived at the beginning of the fifteenth century, declares; viz. that, "a certain hermit and great alchemist of those times, after having labour'd many years in his way, at length discover'd that the great promises of alchemy were vain; whence he betook himself to the preparation of medi-

cines, and commenced physician." *Guainerus* adds, that himself also was obliged to this hermit for communicating to him several good remedies of his own discovering. And after this example it appears, that many other disappointed alchemists turn'd physicians.

Account of Basil Valentine.

(q) "1. *Helmont* has taken pains to shew, that this author was prior to *Paracelsus* by a hundred years; and that he lived in 1415. And some fix his birth to the year 1394.
"2. His writings are much commended, and much sought; tho' there are some spurious pieces tack'd to them. He wrote all in *High-Dutch*; and but few of his pieces have been translated into *Latin*. In experiments he may be depended on for his exactness and veracity; his style is clear, open, and pure; except when he treats of his *arcana*, and particularly of the philosopher's stone; where he is as obscure as the rest.
"3. He should seem to have been the first who applied chemistry to medicine; for after every preparation, he never fails to give some medicinal use thereof. He it was likewise who first broach'd the doctrine of the three chemical principles, salt, sulphur, and mercury, which *Paracelsus* afterwards appropriated; and it might be shewn that *Paracelsus*, *Helmont*, the elder *Lemery*, and many others of modern fame, owe a great part of what is most valuable in them, to this author: so that it is not without reason, that he is judg'd the father of the modern chemists."

* See *Junker*, p. 18. And the appendix to *Stahl's Fundamenta Chémia*.

† See *Hist. de la Med.* p. 784. 786.

‡ See *Guainerus de Parahf.* c. 7.

many of his doctrines. He wrote a multitude of pieces, all very diffusive, and some likewise on the art of physic(r).

Chemical and
alchemical
physicians.

Elated with
some success.

Especially
upon curing
the venereal
disease by the
use of mercury.

Promise
largely.

But perform
little.

31. (11) After the five last mentioned authors appear'd; an opinion got footing among the chemists, as we already intimated, that all diseases of the human body might be radically cured, perfect health restored, and life prolonged to any number of years, by means of one single alchemical medicine. Puff'd up with this notion, wherein they were not a little confirm'd by the efficacy of some violent remedies, procured by chemistry, the chemists began to extend their empire over the whole healing art. At that time physic was overspread with the subtle figments of the schoolmen; and couch'd in words and phrases without meaning; in effect it was *Galenical* all over, and directed absolutely by the decisions of the *Arabs*. Hence the physicians were unable, by their bleeding, purging, and the few efficacious medicines in use, to cure the venereal disease, which had then lately made its appearance. But the chemists attacking it with more powerful medicines, and *Carpus* in particular with *mercury*, discover'd the cure; which increased the triumphs of chemistry and utterly baffled the Schools.

32. This gives us a melancholy idea of the state of the physicians in those times; who, after infinite pains employ'd in enquiring into the nature of the human body, and thence tracing the rise and cure of diseases; had the mortification to find all their laborious writings on ætiologics, diagnostics, prognostics, diætetics, and therapeutics exploded, as idle and useless, by the arrogance of alchemists; who without regarding diet, or attending to the cause and nature of the disease, cured all by the mere application of one single medicine.

33. But this new notion that obtain'd at first, and found many partizans; when it came to be more maturely weigh'd, was found vain, empty and destructive;

" chemists, and the founder of the chemical
" pharmacy.

" 4. *Van Helmont* writ upon the alcahest,
" or universal menstruum; and *Zwelfer*, pre-
" tending to know his secret, describes it as
" a preparation of vinegar and verdigrease
" distill'd, till the verdigrease disappears. But
" *Otto Tachenius* shews, that *Zwelfer* borrow'd
" the whole process from a book of *Valen-*
" *tine's* entitled, *Stangiesst*; where indeed it
" is describ'd in terms plain enough. So the
" *sal volatile oleosum*, which *Sylvius de le Boe*
" has long had the credit of; and many other
" secrets that make a figure in the modern
" authors, are originally derived from *Basil*
" *Valentine*."

(r) His chemical writings are: 1. *Opus ad*
utrumque: printed in the *Theat. Chym.* T. IV.
p. 1061.

2. *De magno lapide antiquorum sapientum*:
on the great stone of the ancient sages. Ex-
tant in *Mang. Bibl. Chym.* T. II. p. 409.

3. *Practica, una cum xii clavisibus, & ap-*
pendice: practice, together with the twelve
keys, and an appendix. Translated out of
Highb-Dutch into *Latin*, and published with
Mich. Majerus's Tripas aureus. *Francos.* 1618.

4to. Also with the *Museum hermeticum re-*
formatum & amplificatum. *Francos.* 1677, and
1678. 4to. And in *Mang. Bibl. Chym.* T. II.
p. 413.

4. *Apocalypsis Chymica*: or, chemical reve-
lation. *Erff.* 1624. 8vo.

5. *Currus triumphalis antimonii*: or trium-
phal chariot of antimony: translated into *La-*
tin, and illustrated with a commentary by
Theod. Kerckringius Amst. 1671. 12mo.

6. *Tractatus chymico philosophicus de rebus*
naturalibus metallorum & mineralium. A
chemico-philosophical treatise, concerning
things supernatural in metals and minerals.
Francos. 1676. 8vo.

7. *Chymische schriften alle, &c.* that is, all
his chemical writings, both printed and ma-
nuscript, enlarged and amended, and divided
into two parts: in *Highb-Dutch*. *Hamb.* 1677.
8vo. with figures. And again, *Hamb.* 1717.
8vo.

8. See also *Basil Valentine's* last will and
testament, with his manual operations, and a
tract of things natural and supernatural. *Lond.*
1671. 8vo. And his triumphal chariot of
antimony, with the true book of *Synepius*, con-
cerning the philosopher's stone.

structive; and the boasts of the chemists appeared to rest only on their own pride. Of this we may find abundant proof in the life and writings of *Paracelsus* and *Van Helmont*, as collected from their own pens.

34. (12) *Aureolus, Philippus, Paracelsus, Theophrastus, Bombast de Hohenheim* (s), was the son of *Wilhelmus Hohenheim*, a learned man, and licentiate in physic; tho' a slender practitioner, but possessed of a noble library; being himself the natural son of a master of the *Teutonic* order. He was born in the year 1493, at a village in *Switzerland* called *Ensdalen*, which signifies a wilderness or desert, about two German miles from *Zurich*; whence he got the appellation of *Eremita*, or hermit, which *Erasmus*, gives him in a letter (t). As appears from the history of Paracelsus.

35. At three years of age he is said to have been mutilated, and made an eunuch by a sow. Accordingly we always find him a bitter enemy of the women; tho' his picture, as taken from the life, represents him with a beard. He was instructed by his father in physic and surgery, wherein he made great proficiency; but as he grew towards riper years he was captivated with the study of alchemy, which occasion'd his father to commit him to the care of *Tribemius* abbot of *Spanheim*; a man of great renown in those days, from whom having learnt many secrets, he removed to *Sigismund Fuggerus* of *Schwartz*, a famous German chemist, who at that time, partly by his own industry, and partly by a multitude of servants and operators, retained for the purpose, made daily improvements in the art. And here he assures us he learnt spagiric operations effectually, after which he applied himself to all the most eminent masters in the alchemical philosophy; who concealed nothing from him, and from whom, as he himself relates, he learnt his secrets.

36. But not resting here, he undertook a journey to all the universities of *Germany, Italy, France* and *Spain*, in order to learn physic; after which he visited *Prussia, Lithuania, Poland, Walackia, Transylvania, Croatia, Portugal, Illyria*, and the other Countries of *Europe*, where he applied himself indifferently to physicians, barbers, old women, conjurers, and chemists both

(s) " 1. *Paracelsus* comes next on the stage; a strange, irregular, unaccountable man; whose history will have the air of a paradox. He reformed and alter'd the face of medicine, and turn'd it into the vein of chemistry. Never did any person bear such different, inconsistent characters. Amidst so much diversity, it will require no small attention and address, to keep the truth in view, and pursue it without deviating into any of the tracks of fable and fiction. To hear the generality of chemists talk, he was nothing less than a god; nay, 'tis a tradition, which I find several peopel believe, that he is not dead, but still lives in his tomb; whither he retired, weary of the vices and follies of mankind. And yet others represent him as one of the most vile, flagitious, and worthless of the race of men.

" 2. To ascertain somewhat of the character of this memorable person, we have consulted all the writers on both sides the

question; and will give his story, not as 'tis drawn by his profess'd devotees the *Paracelsists*; nor yet from those, who determinately vilify him at all adventures, as *Erastus*, &c. but, principally, as delivered by *J. Oporinus*, Greek professor in the same university with *Paracelsus*; *Crato*, an illustrious physician of that time, who conversed with *Paracelsus*; and whose writings have all the marks of candour and exactness; and by *Van Helmont*, who travell'd into *Germany*, on purpose to enquire into the matter, and satisfy himself of the truth of the stories related of our philosopher: tho' as to this last author we shall be a little on our guard; as he appears strongly inclin'd to favour his master, and has publicly declared *Paracelsus* the prince of physicians."

(t) See the original in *Le Clerc Hist. de la Med.* p. 800.

both good and bad; from all which he gladly pick'd up any thing that might be useful; and thus enlarged his stock of sure and approved remedies. He also learnt from *Basil Valentine's* writings the doctrine of the three elements, which, concealing his author's name, he adopted as his own; and published under the appellation of salt, sulphur, and mercury.

37. In the twentieth year of his age, making a visit to the mines in Germany, he travelled on to *Russia*, where being taken prisoner on the frontiers, by the *Tartars*, he was carried before the *Cham*, and afterwards sent, with that prince's son, on an embassy to *Constantinople*; where in his 28th year, he tells us, he was let into the secret of the *philosopher's stone*. He was also frequently retained as surgeon and physician in armies, battles and sieges.

38. He set a high value on *Hippocrates* and the ancient physicians, but despised the scholastic doctors, and above all the *Arabs*. He made great use of remedies prepared of *mercury* and *opium*, wherewith he cured the leprosy, venereal disease, itch, slight dropsies, and other infirmities, which to the physicians of those times, (who were ignorant of *mercury*, and afraid of *opium*, as cold in the fourth degree) were utterly incurable.

The first public
professor of an
alchemy.

39. By these cures he grew daily more celebrated and daring; especially after recovering the famous printer *Frobenius* (u) of *Basil*; by which means he became acquainted with the great *Erasmus*, and well esteemed by the magistracy of *Basil*, who giving him a plentiful salary, made him (x) professor in the year 1527, where he continued to teach philosophical physic two hours every day; sometimes in *Latin*, but oftner in *High-Dutch*. Here he read lectures to explain his own books *de compositionibus, gradibus & tartaro*, on compositions, degrees and tartar; which, according to *Helmont*, abounded in idle drollery, and contained little solid sense. Here, in a solemn manner, seated in the chair, he burnt the writings of *Galen* and *Avicenna*; directing his auditors, if God would not assist them, to consult the devil and him (y)

40. Here he procured many disciples, with whom he lived in great intimacy: three of these he maintained in diet and clothes, and instructed in several secrets; tho' they afterwards ungratefully deserted their master, and even wrote scandalous things of him; administering with great indiscretion the medicines he had taught them, to the great disadvantage of those who employ'd

(u) The case of *Frobenius* appears to have been a violent pain in his heel, which upon *Paracelsus's* treatment, removed into his toes; so that the patient could never stir them afterwards, tho' he felt no pain, and in other respects grew well; but soon after died of an apoplexy*.

(x) After his reception, he publish'd a kind of advertisement, in the month of *June* 1527, where he expresses himself thus: "Being invited, with a large stipend, by the governors of *Basil*, I publicly interpret, for two hours, every day, my own books of practical and theoretical physic, natural philosophy and chirurgery; to the great advantage of my hearers." In this piece

he takes to himself the title of doctor and professor of both the physics, (*viz.* internal and external, or physic and surgery) though, so far as appears, he had only a permission from the magistrate to practise physic in *Basil*, without being receiv'd professor in the university †.

(y) Or declaring to his audience, "that he would even consult the devil, if God would not assist him." The original may bear either translation: but that in the text seems the truest; as being conformable to his express declaration in several places of his work, that "no one need scruple consulting the devil, to get secrets of physic from him."

*See *Le Clerc Hist. de la Med.* p. 799.

† See *Le Clerc Hist. de la Med.* p. 799. not. 3.

ploy'd them. He also retain'd surgeons and barbers in his family; to whom he communicated useful secrets; but all of them soon after left him, and turn'd his enemies. His only faithful disciples were Dr. *Peter*, Dr. *Cornelius*, Dr. *Andrew*, Dr. *Ursinus*, the Licentiate *Pangratius*, and Master *Rapbael*, whom he speaks of with commendation.

41. During his (z) two years residence here, he cured a noble canon of *Liechtenfels*, who had been given over by the physicians, of a violent pain at the stomach, with only three pills of his laudanum. The sick canon had promised him 100 *French* crowns for the cure; but finding it so easily effected, he refused to pay; alledging, with a jest, that *Paracelsus* had given him nothing but three mice-turds. Upon this *Paracelsus* cited him before a court of justice; where the judge, not considering so much the excellency of the art, as the quantity of labour and cost, decreed him a trifling gratification; with which *Paracelsus* was so exasperated, that loading them with reproaches of ignorance and injustice, he render'd himself in some measure guilty of treason; and thus thought best to quit the court, and make haste home. From whence by the advice of his friends, he privately withdrew out of the city; leaving his whole chemical apparatus to *Joan. Oporinus*. After this he continued rambling two years, thro' the neighbouring parts of *Alsatia*, accompanied by *Oporinus*, and in the course of a dissolute life wrought many extraordinary cures; as we find related by *Zwinger* (a), who lived at the same time at *Basil*, and often heard the account from *Oporinus* himself.

42. This *Oporinus*, who had been for some time his servant and amanuensis, was a person of much learning, well skilled in the *Greek* and *Latin* tongues; who, possessed with the vain expectation of attaining *Paracelsus*'s secrets, left his own family and travelled about with him two whole years; without learning any one thing: till weary'd out he grew wise, and quitting *Paracelsus* return'd to *Basil*.

43. It happened, one evening, that *Paracelsus* was called to visit a countryman dangerously ill near *Colmar* in *Alsatia*; but being set in for a drinking-bout, with ordinary company, he deferred visiting the patient till next morning; when entering the house with a furious look, he ask'd if the sick person had taken any physic? as intending to administer some of his laudanum. The by-standers answered, he had taken nothing but the sacrament; as being at the point of death: at which *Paracelsus*, in a rage reply'd; if he has had recourse to another physician, he has no occasion for me; and ran immediately out of doors. *Oporinus*, struck with this piece of impiety, bid *Paracelsus* the last adieu; fearing the barbarity of his otherwise lov'd master should some time fall on his own head (b).

44. From this time *Paracelsus* having forgot his *Latin*, continued wandering from place to place; always fuddled; never changing his clothes, nor so much as going into a bed: till the month of *September* 1541, when being taken ill at a public inn, at *Saltsbourg*, he died after a few days sickness, in the

(z) He came to *Basil* in 1527, and had left the place before *June* 8, 1528^m.

(a) *Theat.* 1422.

(b) *Zwinger. Theatr.* 2275.

* See *Le Clerc Hist. de la Med.* p. 799, 801.

the 47th year of his age: tho' he had promised himself, by the use of his *Elixir proprietatis*, that he should live as long as *Mathusalem*.

His works.

45. Some of his works were published by himself, particularly the fourth part of his, 1. *Cbirurgia magna*, or great surgery, which he dedicated to *Hieron. Bonerus*, dictator of the city *Colmar*, June 2. 1528. Also, 2. *Liber Apostematum*, his book of apostems, which he dedicated to *Conrad Wiserum*, consul of *Colmar*, July, 5th, 1528. Then, 3. *De gradibus, compositionibus & tartaro*, his books of degrees, compositions and tartar. 4. His great surgery, which he dedicated to the emperor *Ferdinand* from *Munich*, May 7. 1536. And 5. the second part to the same prince, August 11. 1536. In these he makes mention of several other pieces published by himself, viz.

6. *De archidoxis*. Archidoxa.

7. *De sanationibus*. Of cures.

8. *De sanitate microcosmi & elementorum*. Of the healthfulness of the microcosm and the elements.

9. *De generationibus naturalium*. Of the generation of natural things.

10. *De suppuratione*. Of suppuration.

11. *De signis*. Of signs.

12. *De characteribus & adeptis*. Of characters and adepts.

13. *De phlebotomia*. Of phlebotomy.

14. *De origine novorum morborum*. Of the origin of new diseases.

15. *De magia*. Of magic (c).

All these particulars I have collected with much pains, from the writings of *Paracelsus* himself, *Oporinus*, *Zwinger*, and especially *Van Helmont* (d), as not daring to take any thing deliver'd by other persons, where prejudice and partiality are too apparent (e).

46.

(c) See also the following: 1. *De gradibus & compositionibus receptorum & naturalium*, Lib. vii. dedicated to *D. Eph. Clauserus*, a physician of *Zurich*. Bas. 1526. 4to.

2. *Archidoxorum* Lib. x. dedicated to the students of *Zurich*. Bas. 1527. 4to.

3. *Aur. Theophr. Paracelsi archidoxorum, seu de secretis naturæ mysteriis, libri x. quibus nunc accesserunt libri duo, unus de mercuriis metallorum, alter de quinta essentia; manualia item duo, quorum primus chemicorum verus thesaurus; posterius præstantium medicorum experientiis refertum est; ex ipsius Paracelsi autographo*. Bas. 1582.

4. *Paramirica opera*; dedicated to *D. Joach. Vadianus*, a physician. 1531. March 5.

5. *De natura rerum*, Lib. viii. dedicated to his friend *Job. Winckesteiner* of *Friburg*. 1537.

6. *Opera omnia*, in two volumes, folio, Latin.

7. There is likewise an English translation of his *Archidoxa*, by *J. H. Oxon*. 1661. 8vo.

(d) Vid. *Helm*. p. 181. §. 3. p. 324, 325, 698, 699.

Account of Paracelsus.

(e) " 1. No wonder *Paracelsus*, in his time, was esteem'd an excellent physician and sur-

geon; for medicine was then in a low condition: the practice and the very language was all *Galenical* and *Arabian*. Nothing was inculcated but *Aristotle*, *Galen*, and the *Arabs*; *Hippocrates* was not read: nay, there was no edition of his writings; and scarce was he ever mention'd. Their theory consisted in the knowledge of the four degrees, the temperaments, &c. and their whole practice was confin'd to bleeding, purging, vomiting, and glysters.

" 2. What contributed still more to his reputation, was, his becoming acquainted with the excellency of mercury in the venereal disease, which had then newly broke out, and spread itself over *Europe*. And probably he had the hint of this from *Jac. Carpus*, a celebrated anatomist and surgeon at *Boulogne*, who alone had been master of the cure; which was effected by means of mercury, applied so as to raise a salivation.

" 3. 'Tis probable that the bulk of the pieces publish'd under this author's name are not his, but that his followers chose to usher their performances under that cover. In effect, they are so many, and so diffe-

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46. (13) *John Baptist Van Helmont*, was born of a noble family, at *Brussels*, 1577. in the year 1577, viz. 36 years after the death of *Paracelsus*. He lost his father

Van Helmont.

“rent from each other, that 'tis next to impossible they should all come from the same hand. And yet, besides the three books which he lectur'd in public, there are some others that should seem to be genuine: such is that *de peste*, of the plague; that *de mineralibus*, of minerals; that *de vita longa*, of long life; and the *archidoxa medicina*, which was publish'd by *Bodensleyu*, while *Paracelsus* was living, or at least soon after his death.

“4. This work is called *archidoxa medicina*, as containing the principal rules and maxims of the art. Nine books thereof were publish'd at first: and the author in the *prolegomena* to them speaks thus. [I intended to have published my ten books of *archidoxa*; but finding mankind unworthy of such a treasure as the tenth, I keep it close in my *occulup*; and resolve never to bring it thence, till you have all abjured *Aristotle*, *Avicenna*, and *Galen*, and have sworn allegiance to *Paracelsus* alone.]

“5. However the book did at length get abroad; tho' by what means is not known: it is confessedly an extraordinary piece, and may be rank'd amongst the principal productions that have ever appear'd in chemistry. Whether or no it be *Paracelsus*'s we will not affirm; but there is one thing speaks in its behalf, viz. its containing many things which have been since cried up for great nostrums; and *Van Helmont*'s *lichontripic* and *alcahest* are apparently taken hence. The following passage of *Helmont* may have occasion'd much speculation: [“To distil the volatile spirit of sea salt, in order to dissolve the stone in the bladder, digest sea salt for a month with juice of horse-radish; and then distil the whole: what rises is the spirit of the salt; of singular efficacy in dissolving the stone either in the bladder or kidneys.”] How *Helmont* came to know that sea salt would ferment with radish-juice is surprizing; there being no hint of the thing in any of his other writings: but our wonder will cease upon reading the process in express terms in the tenth book of *archidoxa*. And the whole book of the *alcahest* is apparently taken from the same.

“6. Amongst the genuine writings of *Paracelsus*, are likewise reckon'd that *de ortu rerum naturalium*, *de transformatione rerum naturalium*, and *de vita rerum naturalium*.

“The rest are spurious, or very dubious at best; particularly the theological works.

“7. With respect to his merits as to medicine and alchemy; it must be own'd that an arrogant assuming air infected all his writings, as well as his actions: it was common with him to promise mighty things with compleat assurance, upon slender and unequal grounds. A strong instance of his weakness in this kind is his undertaking, by the mere use of his *elixir proprietatis*, to prolong a man's life to the age of *Methusaleb*; and deliberating with himself to what period he should protract his own. This argues his trusting to imagination more than experience: for, as he died a young man himself, 'tis certain he could not have experiments sufficient to warrant any such thing; nor did he speak of his own knowledge, as a physician ought to do, but purely out of caprice.

“8. We know not how it is, but the body of chemists, both of his and our times, have complimented *Paracelsus* with the knowledge of the universal remedy; and he himself is at the head of the opinion: he swears by his own soul, and calls every god in heaven to witness, that with one single remedy prepared from metals, he was able to cure all diseases, be they what they would. But *Helmont*, who knew as much of *Paracelsus* as any man, does not believe a word of it; and tho' he is always commending him, warns us not to trust him; adding, that his writings are full of babble. His own history affords no great proofs of the thing; nor have we any competent testimonies of other writers. But what effectually overthrows his pretensions to such a remedy, is his own dying at an immature age.

“9. His real merit consisted, 1. In being well skill'd in surgery, and practising it with great success. 2. In understanding the common practice of physic, as well as his contemporaries. 3. In being alone master of the powers, preparations, uses, &c. of metals. 4. In having the use of *opium* to himself, and working wonderful cures thereby. And, 5. In being well acquainted with the virtues of mercury, in an age, when only he and *Carpus* knew any thing of the matter.

“10. As to his being possess'd of the philosopher's stone, there are no sufficient proofs

father in 1580; and being the youngest child, apply'd himself, against the consent of his mother, and without consulting his friends, to the study of
 physick

"proofs of it, and many strong ones to the contrary."

11. The judicious M. Le Clerc has given an excellent sketch for the history of *Paracelsus*, at the close of his *history of physic*; the conclusion of which sketch, as summing up the evidence, and setting the matter in a clear light, may be acceptable in this place. "His manners and his conduct are not to be defended. In reading his works, it is easy to observe that he had a heated and disorder'd imagination, full of the crudest notions: whence it is no wonder he gave into astrology, geomancy, chiromancy, and the cabbala; which were extremely common and popular things in those ignorant ages. He says expressly that medicine must be join'd to magic, or it cannot be successful; by which he does not mean natural magic only, but declares that no one need scruple getting certain secrets of physic from the devil; and boasts of holding conversation with *Galen* and *Avicenna* at the gates of hell. In short, he has used all the possible means to persuade the world that he was a real magician; so that if he has fail'd in the attempt, it is his misfortune. Indeed, it has been the common opinion that he was one; but for my part, I judge he was rather an impostor than a conjurer."

12. But among the bad things that his works are stuffed with, there are some that are good, and contribute to the improvement of physic. What he says against the common notions that had prevail'd from the time of *Galen*, as to the effects of the primary qualities of bodies, *viz.* hot, dry, cold, and moist, has somewhat open'd the eyes of physicians. He calls the philosophy of *Aristotle*, a wooden foundation; and if himself has not laid a better, he has given occasion for it, and promoted a discovery of the weakness of that old basis. His opinion of seeds, all which he supposes exist from the beginning, prevails to this day among the most knowing, who have only explain'd it better. His doctrine of *salt*, *sulphur*, and *mercury*, has great uses in philosophy and physic; if taken not as real elements, but as active principles in bodies. It is also manifest, that he had a great knowledge of the *materia medica*, and bestow'd much time and pains in working upon animal, vegetable, and mineral

substances; so as to have made a very large number of experiments; but then he has this great defect, that he studiously conceals, what a long course of experience had taught him upon this subject; so that the short critic of *Gunther d' Andernac** is extremely judicious: ["I allow, says he, that *Paracelsus* was an excellent chemist, and that he has deliver'd many good things in his writings; but, on the other hand, it is pity he should have mixed them with a number of others that are false and frivolous; and at the same time have cover'd the best of all with so much obscurity, that scarce any one can understand what he says, or make the least advantage of it. I wish *Galen* had been less diffusive and more exact in his works, and *Paracelsus* more clear and candid; but as every one has his failings, we should retain what appears to be good, and leave the rest."]

13. The Lord *Bacon* has given a just tho' severe, censure of *Paracelsus*, in his philosophical capacity, to this effect: "*Paracelsus*, standing at the head of the chemists deserves to be separately chastised as a monster. What *Bacchanalian* oracles are those he utters in meteorology; whilst he is ridiculously aping of *Epicurus*? All that *Epicurus* asserts upon the subject is but opinion, which he unconcernedly left to its fate; but *Paracelsus*, blinder than fate, and more rash than chance, is ready to avouch the absurdest falsehoods. What dreams of resemblances, correspondences, and parallels are given us by this fanatical linker-together of idols? His three principles indeed might be receiv'd with some utility, as having a foundation in nature: but he is continually wrestling them to every thing, according to his great dexterity in delusion. But this is not the worst of him: for like a sacrilegious impostor, he has mixed and polluted divine things with natural, sacred with profane, fables with heresies, and human truths with religious; so as not like the ancient *Sophists* to have hid, but extinguish'd the light of nature. The *Sophists* were only deserters of experience, but *Paracelsus* has betray'd it. At the same time he is so far from understanding, or justly representing experience, that he has added to the trouble and tediousness of experimenting. In short, he has every where, to the utmost, magnified

* *De Vir. & Nov. Med. T. 2. p. 651.* *Guntherius* was cotemporary with *Paracelsus*, being born in 1497, and dying in 1574.

physic (e). He finished his course of philosophy in the year 1594, being the 17th of his age (f), when he was noted for a great reader, having read *Galen* twice, *Hippocrates* once, and all the other physicians, both *Greeks* and *Arabs*, with great care; and even common-placed the more remarkable passages in them. When, going to *Lovain*, he was appointed, by the professors *Thomas Tyenus*, *Gerard Villers*, and *Hornius*, to read public lectures on chirurgery, in the college of physicians (g). In the 22d year of his age, being the year 1599, he was created doctor of physick, at *Lovain* (h), where he had began to see thro' the insufficiency of the school-physick, long before he had discovered any better medicines of his own (i). Happening to be troubled with a slight itch, which he could not get rid of by the school-method, but which was easily removed by means (k) of sulphur, he repented having ever devoted himself to the study of physick; considering the nobleness of his birth, and that none of his family had hitherto stooped to such a profession. On these motives he threw it up; divided his fortune among his relations; and quitted his country; with an intention never to return (l). His books to the value of 200 crowns, he threw aside (m); and setting out for foreign countries, rambled ten whole years (n); till being instructed in chemistry by a certain illiterate person, he apply'd himself wholly to that art: and having in the compass of two years obtained a few chemical medicines (o), he became capable of curing some diseases.

47. In the year 1609, he married a rich, noble, and virtuous wife, with whom he retir'd to *Wilkoord*, where he gave himself wholly up to the pursuits of chemistry (p): during his noviciate in the art, he tried many dangerous experiments, which frequently hazarded his life (q). And tho' he did

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not

"fied the absurd pretences of magicians,
"countenanced such extravagancies, and en-
"couraged others to believe them from his
"own assurance; being thus at once the work
"and servant of imposture. — His disciples
"greedily swallow those doctrines, which he
"has rather promulged and promised, than
"actually laid down and made good, and de-
"fended with arrogance instead of caution;
"being thus recommended with pompous
"shew, affinity with religion, the subterfuge
"of obscurity, and other impostures. And
"hence his followers appear link'd to one
"another by the lying spirit, that shews itself
"in their swoln hopes and promises. How-
"ever, by wandering through the wilds of
"experience, they sometimes stumble upon
"useful discoveries; not by reason, but by
"accident: whence proceeding to form the-
"ories, they plainly carry the smoke and
"tarnish of their art along with them; and
"like childish operators at the furnace, at-
"tempt to raise a structure of philosophy with
"a few experiments of distillation; and their
"own idols of separation and mixture, where
"no traces of them are really found. Yet

"we do not accuse them all in the lump; but
"make a difference betwixt that little ser-
"viceable set, who being not very solicitous
"about raising of theories, principally prac-
"tise a certain mechanical subtilty in making
"new discoveries, with their uses; more after
"the manner of *Friar Bacon* than *Paracelsus*;
"and distinguish these from that impious
"tribe, who endeavour only at procuring ap-
"plause to their theories, and court and beg
"it under a pretended zeal for religion, large
"promises, and the arts of imposture; which
"is the way of *Basil Valentine*, and most of
"the alchemical authors."

(e) Vid. *Helm.* p. 833.

(f) P. 12. §. 1.

(g) P. 833.

(h) P. 11. §. 7.

(i) P. 423. §. 2.

(k) P. 256. 257.

(l) P. 833.

(m) P. 666. §. 12.

(n) P. 11. §. 12.

(o) P. 833.

(p) P. 41. §. 7. p. 833, to 888;

(q) P. 719, 948.

* See Lord *Bacon's* works, 4to. Vol. II. p. 55, 56.

not visit patients and practise physic for gain (r), he assures us he cured every year some thousands of sick people (s). He spent fifty whole years in distillations (t). He was in high esteem with the electoral bishop of Cologne, a prince eminently skill'd in chemistry; and was invited by the emperor Rudolph, and two other emperors, to the court of Vienna; but he always refus'd (u). In the year 1624, he published a treatise, printed at Liege, *de aquis Spadanis*, or, of the Spaw waters, and afterwards several other pieces (x).

48. He was not able to cure two of his sons, whom he lost of the plague (y), nor his eldest daughter of a leprosy, tho' he practised on her full two years (z). Nor could he cure his wife, nor his maid, nor himself, of poison (a). In January, 1640, being the 63d year of his age; he was seized with a fever, attended with a slight shivering, which made his teeth chatter; a pricking pain about the *Sternum*, a difficulty of respiration, and a spitting first of bloody matter, then of pure blood. For the removal hereof, he took shavings of the penis of a stag, upon which the pain grew less; than he took a dram of goat's blood, and the spitting of blood stop'd for four days; leaving only a slight cough, with a moderate expectoration: but the fever still remained, and was followed by a pain in the spleen; for which he took wine boil'd with crabs-eyes; whereupon all the symptoms disappeared (b). In the year 1643, he was seized with a *Syncope*, occasioned by the smoak of charcoal (c), which he cured with sulphur of vitriol (d). On the 18th of November, 1644, he fell into an asthma, attended with two fits of a pleurisy; and after languishing seven weeks, died of a slight fever and extreme weakness, on the 30th of December, 1644.—See his son's preface to all his father's works, which he published after his father's death (e).

(r) P. 693. §. 3.

(s) P. 835.

(t) P. 241. §. 1.

(u) P. 833, 835.

(x) See his *Opuscula medica inaudita*. Col. Agr. 1644. 8vo.

(y) P. 873.

(z) P. 714. §. 27.

(a) P. 469.

(b) P. 332. §. 35.

(c) P. 242. §. 19.

(d) Ibid.

Account of Van Helmont's Works.

(e) " 1. During the retirement of this author at *Witvoord*, he examin'd, with great pains and industry, all kinds of bodies, both fossil, vegetable, and animal, in a chemical way; and thus first furnished a new body, or course of chemical knowledge. Here he made those noble experiments and discoveries of oil of sulphur *per campanam*, the *laudanum Paracelsi*, spirit of hart's-horn, spirit of human blood, *jal volatile oleos*, &c.

" 2. Having conceiv'd a strong prejudice against the *Galenical* method and medicine;

49.
" from his own ill success upon applying them in practice; and finding chemistry productive of so many, and much more powerful remedies, he run counter in every thing to the *Galenic* school, and reduced the whole art of physic to principles of chemistry. With such views he began to write: his first piece was of *Spaw-waters*, printed at Liege in 1624, as above-mention'd; which procured him considerable esteem: there are several good things in it, and but little of that opinionativeness and boasting, which shew'd itself in his later works. He had it reprinted the same year at Cologne, with new experiments. In 1644, he publish'd his second piece, *de humoribus, of the humours*; a third, *de febris, of fevers*; and a fourth, *de lithiasi, of the stone*; which are all the books he publish'd in his life-time. Soon after the publication of the last he died: so that the suggestion of some eminent chemists, that Helmont had chang'd his sentiments, and had got quite other things in view, appears without any ground.
" 3. As he perceiv'd his death approaching, he call'd for his son, and gave him the following

* See his *Opuscula medica inaudita*. Col. Agr. 8vo. 1644.

49. Hence it evidently appears that these two authors, *Paracelsus* and *Helmont*, who are the heads of all the chemical physicians, were not masters of the universal remedy, which they so often boast of; but in chronical cases frequently wrought extraordinary cures by means of violent remedies, where the constitution of the patient was strong enough to endure the action thereof. But for all their vain promises of long life, neither of them arrived at old age. They were succeeded by the following famous physicians.

50.

following charge [“ Take all my writings, the crude as well as the finish’d ones; and join them together: to your care I commit them; do with them what you think good. For so, it has pleased almighty God, who directs every thing to the best purposes.] This son was a person of deep thought, but a little tainted with enthusiasm; and in his father’s life-time had stroll’d about with a gang of gypsies. After the father’s decease, he acquitted himself of the trust; publishing them just as he found them, without any regard to order, consistency, or correctness; and beside, trusted the impression principally to the printer: so that we frequently find *Helmont* relating things in one place, which he contradicts in another. And indeed ’tis no wonder we don’t find the same tenor throughout; for as chemistry grew under his hands, and as many new views must turn up in forty or fifty years, which he spent in gradually improving the art; it is easy to conceive how there should arise a difference.

4. The pieces published by himself are all excellent: that of *the stone* is incomparable, and the best: that of *fevers* is a valuable work: and that of *the humours* is a fine piece. The *Galenical* doctrine of the four elements, four qualities, four degrees, and four humours, with the method of cure by tempering these degrees, are here clearly and directly prov’d to be false and insignificant. The treatise of *the plague*, which is one of the posthumous pieces, has many good things, tho’ it does not come up to the merit of the former. But the rest are all so much inferior, that one would never suspect them to have come from the same hand.

5. The best edition is that of *Amsterdam*, in quarto, apud *Elsevir*. In the *Venetian* edition in folio, there are several pieces not *Helmont’s*: and the same may be said of that lately publish’d in *Germany*.

6. If his most solemn protestations are of any weight, he should seem to have been possess’d of the universal medicine: a thing which he inculcates in almost all his writings.

His notion of the origin of such an universal remedy, is very peculiar and savours of that enthusiasm, which was a part of his character. No poison, says he, can act on a carcass: there must be life to produce an effect: this life he calls *archæus*; and ascribes both knowledge and understanding thereto. If now any heterogeneous body happen to be present to the *archæus*, it rises into a fervour, endeavours to expel the hostile matter, and in order to that, exerts all the force of the body. To cure any disease, therefore, is to pacify and compose this *archæus*. The thing required, therefore, is such a remedy as may readily calm, and put a stop to this unnatural fervour upon all occasions; and this, says he, is the universal remedy.

7. This doctrine of *Helmont* would not be so absurd, did he not ascribe understanding to his *archæus*. Setting this aside, the principal which renders poisons deadly, and remedies beneficial, is the circulation of the blood. No doubt but *Helmont* was appriz’d of this before he died. For *Harvey* had published his discovery some years before; which *Helmont* could not but fall into: tho’ he might chuse to dissemble the matter, as it untwisted a large part of his system; which he might want leisure or inclination to reform and model anew.

8. From *Paracelsus’s* and *Helmont’s* time, the number of chemists and chemical writers grew immensely; so that to rehearse them all would be endless. In *Borelli’s biblioteca chymica*, printed at *Heidelberg* in 1653, no less than four thousand writers, already extant, are enumerated; and yet he mentions none but those of his own knowledge. Others, who took more scope, found above double that number at the same time. It may be added, that the years elapsed since, have produced more than all the ages before.

9. Here, therefore, we must end our career; the field is too vast to enter on. We have conducted chemistry from its rise to its state; its progress is now at an end: we shall only here observe, that as it is not only a dark and intricate, but a dangerous

The History of CHEMISTRY.

50. Francis de le Boe Sylvius, Otto Tachenius, and their followers, contributed still further to the introduction of chemistry into medicine; so as to render the latter intirely dependant, both as to practice and speculation, on the former.

Method of
studying che-
mistry.

From the whole of what has been hitherto delivered, it appears most advantageous to a novice, at his entrance on the study of chemistry, to begin with perusing the authors who have reduced the operations into the form of systems: The chief of which are the following.

CLASS I. Systematical Writers.

Writer's of
systems.

51. (1) Oswald Crollius (f), in his *Basilica chemica* (g) cum notis Jo. Hartmanni. Genev. 1658. 8vo.

52. (2) Beguinus in his *Tyrocinium chemicum*, often printed in 8vo. and 12mo (h).

" art; so he who enters on it, must proceed,
" not only with address, but caution. That
" part which relates to metals, is remarkably
" dangerous: The single vapour of arsenic
" may either immediately suffocate, or occa-
" sion a weakness for ever; and an author
" who relates an experiment, without expre-
" sing every circumstance thereof at large, is
" not only useless, but even dangerous. The
" event of every operation depends on these
" minute circumstances; and an alteration in
" any one, may not only prevent the success
" of the whole, but even render it unexpect-
" edly fatal. We proceed therefore to single
" out of this vast number, those we would re-
" commend for their exactness and fidelity,
" in teaching the fundamental parts of che-
" mistry: and these we shall reduce into four
" classes. (1.) The first class includes the sys-
" tematical writers, or those who have col-
" lected all the known operations into a body,
" and digested them in the form or order of
" an art or institution, for others to learn by;
" commonly with some addition of their own
" reasonings at the end of each operation.
" (2.) The second class will contain the me-
" tallurgical writers. (3.) The third will
" comprehend the authors on alchemy. And
" (4.) The fourth those that have applied che-
" mistry to the uses of natural philosophy,
" medicine, and other arts."

Account of Crollius.

(f) Crollius was a Hessian, and physician in ordinary to Christian, prince of Anhalt. He was a person of learning, but a sanguine follower of Paracelsus; even in his extravagancies about astral virtues, signatures, chiromancy, physiognomy, gnomes, sylphes, parallels, and resemblances of celestial and sub-lunary bodies; on which he endeavours to found the art of physic. And yet the chemi-

cal processes he describes are generally faithful and exact. He dedicates his book to the prince of Anhalt, from Prague 1608. It shews the ways of preparing several chemical medicines, which are now commonly known.

His Works.

(g) The original title is, *Basilica chymica, philosophicam, propria laborum experientia confirmatam, descriptionem & usum remediumum chymicorum selectiss. & lumine gratia & naturae desumptorum continens*; that is, the chemical court, containing the philosophical description, and use of the choicest chemical remedies, drawn from the light of nature and grace; and confirm'd by his own experience.

— At the end is added, the same author's *Tractatus novus de signaturis rerum internis*, or a new treatise of the internal signatures of things, Francof. 1609. 4to. Reprinted in 1611, 4to. 1620. 4to. and 1622. 8vo.

— Cum augmento Jo. Hartmanni. Lipf. 1634. 4to.

— Genev. 1630, 1635, 1643, and 1658, 8vo.

— In High-Dutch, under the title of *Basilica chymica, Oder Alchymistisch Künigl. Kleinod*, &c. Francof. 1623 and 1647. 4to.

— Traduit en Francois, par Marcel, a Rouen 1634. 8vo

Account of Beguinus's Works.

(h) Beguinus was almoner to the king of France, and publish'd.

1. *Les elements de chymie*, à Paris 1615, and 1624, 8vo. à Genev. 1624. 8vo. à Rouen 1637. 8vo. à Lyon 1665, 8vo.

These were translated into Latin, and illustrated with notes, by Jer. Barthelemy, under the title of *Tyrocinium chymicum*. Francof. O. 1618. 8vo. Afterwards enlarged above one half, with notes, and select forms of medicines, by Christoph. Gluckstadt. Regiomont. 1618.

8vo.

53. (3) *Jo. Hartmannus*, in his *Opera medico-chymica*, 1690. Fol. (i).
 54. (4) *Christoph. Glaser*, in his *Traité de la chymie*: Brussels 1676 12^o. (k).
 55. (5) *Nicholas le Febure*, in his *Traité de la chymie*. à Paris 1660, & 1669, 2 vol. 8vo. & à Leyd. 2 vol. 1669. 12mo. (l).
 56. (6) *Lemery*, in his *Cours de chymie* (m). Leyd. 1716, 8vo (n).

8vo. Afterwards republifh'd with the notes of both these editors, as also the forms of medicines, digested into one system, by *Jo. Geo. Pelfhofer. Witteberg*. 1650. 8vo. Lastly, illustrated with a new comment, by *Gber. Blasius. Amst.* 1659. 12mo. Of which another edition enlarged and corrected was publifh'd, *Amst.* 1669. 12mo. This work is also translated into English by *Richard Ruffel*, under the title of royal and practical chemistry.

(i) *Opera omnia medico-chymica, collecta & in unum volumen congesta, atque pluribus aucta*, à *Conr. Johrenia. Francof. M.* 1684. Folio ibid. 1690.

Praxis chymiatrica, publifh'd by *Jo. Michaelis*, and the author's son *Everb. Hartmannus. Lips.* 1683. 4to. And with the addition of three other pieces, *Genev.* 1639, 8vo. and 1682. 8vo.

Account of *Glaser* and his Works.

(k) *Cbr. Glaser* was apothecary in ordinary to the king of France, and the duke of Orleans, and gave public lectures on chemistry and chemical preparations, in the royal garden at Paris. His book is candidly and clearly wrote, and contains a little system of chemical processes, for making chemical medicines in an easy and effectual way. He keeps close to the describing of such operations as himself had frequently repeated, without intermixing any foreign theory. The book is short, and fit for beginners. The original was printed at Paris in 8vo, 1688. It is also translated into English by *Walter Harris M. D.* and fellow of the royal society, under the title of the *Compleat chymist, or a new treatise of chymistry: teaching by a short and easy method, all its most necessary preparations. London* 1677. 8vo. It was also published in *High-Dutch*, under the title of *Chemischer wegwijzer*, &c. Jan. 1710. 12mo.

Account of *le Febure* and his Works.

(l) "*Nic. le Febure* was royal professor of chemistry, and apothecary to the household to king *Charles II.* He also flourished in the court of France, as chemist to *Louis XIV.* The best edition of his works is that in 12mo. He is highly to be commended, both for deliveting the art, with all the processes, and precisely noting all the minute circumstances. He is very faithful

and accurate in relating his experiments, and particularly careful in pointing out all the dangerous and fatal processes: but he has this defect, that in his reasonings he has too much of the chemical spirit; and talks too largely of the virtues of his medicines. Mr. *Boyle* quotes him under the characters *L. F.* and mentions his *ens primum* of baulm, whereby he pretended to restore youth and vigour to old worn out animals."

His *Traité de la chymie* was translated into English by *P. D. C. Esq.* and printed at London 1670, in 4to, and is entitled, *A compleat body of chemistry, in two parts: containing whatever is necessary to be known in this art, with the whole practice of it.*

Account of *Lemery's Works.*

(m) *Nic. Lemery*, *cours de chymie, contenant la maniere de faire les operations qui sont en usage dans la médecine, par une methode facile. à Paris* 1675, 8vo. *Lyon* 1724. 8vo. In Latin, *Gen.* 1681. 12mo. In *High-Dutch*, *Dresden* 1697. 8vo. In English by *Walter Harris, M. D.* second edit. *London* 1686. 8vo. and fourth translated from the eleventh edition of the French. "The best edition of the original is that of Paris in 8vo, 1713, which has many things not in any of the preceding ones. It contains the principal operations belonging to the three kingdoms; all which are describ'd with candour and accuracy. To each are added notes, containing the physical reasons thereof: but his reasonings are not to be trusted. He is every where minute in enumerating all the circumstances of the processes, and particularly where any danger might arise.

"This performance of his has gone thro' many additions in various languages; and yet it is ill concerted for such a study the art: he begins with the very hardest part, metals, a great number of his processes are merely calculated for the preparing of remedies; and his view, throughout the whole, is rather to furnish the shops with medicines, than to instruct his readers in the knowledge and grounds of chemistry. But how hard is this, to make an art a drudge to phisic, which, in reality, is the principal part of natural philosophy!"

Account

57. (7) *Le Mort* (n) in his *Chymia medico-physica*, &c. Lugd. Bat. 1696, 4to.
 58. (8) *Barchusen* (o) in his *Pyrotophia*. Lugd. Bat. 1698, 4to (p).

CLASS

Account of M. Lemery the elder.

His Works.

1. Monsr. Lemery was born at Rouen in 1645. He got his first notion of chemistry from an apothecary of the place, to whose care he was committed; but not content with this, he went to Paris, and there applied himself to Monsr. Glauber. Afterwards he travell'd for improvement; and at the end of six years return'd to Paris an accomplish'd chemist. Here he exhibited his first course of chemistry in the laboratory of his friend M. Martin, apothecary to the prince of Condé; and afterwards open'd one of his own, which was soon resorted to both by natives and foreigners: so that Paris was then the seat of chemistry.

2. He was the first who began to dissipate the affected obscurities of chemistry; reducing it to more simple and determinate ideas, throwing out a deal of the jargon, and accommodating it to the taste and philosophy of the time.

3. In 1675, he printed his *course of chemistry*, which was receiv'd with great applause; and translated into several languages. But he still reserved some of his secrets; and is even said to have contented himself with making several of the operations more easy than they had been; without revealing the utmost degree of facility he was acquainted with.

4. In 1681, the religious troubles coming on, M. Lemery, who professed the reformed religion, was soon obliged to lay down his courses: upon which the elector of Brandenburg invited him to Berlin; but he declined it, and came over to England, where he was favourably receiv'd by king Charles II. But matters not answering his expectations here, he return'd to France, and took the degree of doctor in *physic* at Caen; but the edict of Nantz in 1685 prohibiting the practice of *physic* to those of the religion, he was entirely stript of all employment. Hereupon he embraced the Roman Catholic faith, and thenceforward applied himself to pharmacy; and in 1697 publish'd two large volumes, one of them entitled, *Pharmacopœia universelle*, the other *Traité universelle des drogues simples*.

5. Upon the revival of the royal academy in 1699, he was elected *associated chemist*; and soon after, upon the death of M. Bourdelin, *pensionary chemist*. Here he read his *Traité d'antimoine* at several times: after which he began to droop under old-age; surrender'd his place in favour of his son, and died of an apoplexy in 1715.

6. Besides his pieces above mention'd, there are several papers of his in the *French memoirs*; viz. 1. An explication of the effects of volcano's, thunder, &c. *Mem. de l'Acad. Royal de Scienc.* An. 1700. p. 131. 2. On camphire. *An.* 1705. p. 47. 3. On honey, and its chemical analysis. *An.* 1706. p. 352. 4. On cow's urine, &c. *An.* 1707. p. 50. 5. On corrosive sublimate. *An.* 1709. p. 50. 6. Observations upon an alchemist eating *mercurius dulcis*. *An.* 1699. p. 69. See also *Traité de l'Antimoine, contenant l'analyse chymique de ce mineral, & un recueil d'un grand nombre d'operations*, &c. à Paris 1707. 12mo. *Observations critiques sur le traité de l'antimoine, de M. Lemery.* à Paris 1707. 12mo. *Reponse de M. Lemery aux observations critiques sur son traité de l'antimoine.* *Vide Mem. de Trev.* Dec. 1707. p. 2084.

Account of Le Mort.

(n) *Le Mort* was professor of chemistry in the university of Leyden, whom our author immediately succeeded. He was a good practical chemist, and explains the operations of the art distinctly, by means of the art itself; of which he was a warm patron, and zealous defender. But many of his processes are such as have long since been disused. He will by no means allow of mathematical and mechanical explanations in chemistry; nor the doctrine of attraction; and is extremely severe upon a very learned *English* physician, who attempted to explain the operations of chemistry by their assistance. His works are the following.

His Works.

1. *Jac le Mort chymia vera nobilitas & utilitas in physica corpusculari, theoria medica, ejusque materia & signis ad majorem perfectionem deducendis.*

2. *Pharmacia medico-physica, rationis & experientia nobilitata.*

3. *Chymia medico-physica.*

4. *Metallurgia contrahæ*: to all which are subjoin'd, *Collegia chymica Leydensia*, &c. Lugd. Bat. 1696. 4to. with copper plates.

5. *Jac le Mort de concordantia operum naturæ & chymia.* Lugd. Bat. 1702. 4to.

6. *Le Mort facies ac pulchritudo chymia ab asfællis maculis purificata, & ad veras naturæ & sue artis leges exornata.* Lugd. Bat. 1712. 8vo. *Vid. Ab. Erudit.* Lips. 1712. p. 543.

Account of Barchusen.

(o) "*Johannes Conradus Barchusen* was professor

CLASS II. Metallurgical Writers.

59. In the metallurgic (p) part the principal writers are,
 60. (1) *Geber*, whose writings have been often reprinted in different forms (q).
 61. (2) *George Agricola de re metallica Lib. xii.* 8^c. Basf. 1657 (r).

62.

"lessor of chemistry at *Utrecht*; and deserves well to be read, as he is an honest writer, and sufficiently accurate; and delivers good matter in an excellent style; tho' his reasoning perhaps may be faulty. His *elementa chymiae* are printed in 4to, and contain several particular experiments, and manual operations no where else to be met with."

His Works.

1. *Jo. Conr. Barbusen pyrotophia, succincte atque breviter iatro-chemiam, rem metallicam & chrysopaeiam peruestigans.* Ludg. Bat. 1698. 4to. with copper-plates.

2. *Acroamata, in quibus complura ad iatro-chemiam atque physicam spectantia, jucunda rerum varietate explicantur.* Traj. Bat. 1703. 8vo.

3. *Elementa chemiae, quibus subjuncta est consuetudo lapidis philosophici, imaginibus representata.* Lug. Bat. 1718. 4to.

(p) "By metallurgy is meant the whole art of preparing and working metals from the glebe, or ore, to the utensil. This part of chemistry, therefore, is employ'd in the finding, digging, washing, purifying, and melting of ores, and rendring of metals malleable; and consists of four parts: the first teaches how metals and ores grow in the mine, how they are discovered, and how dug, or procured: the second shews how to separate the metallic parts from the other matters of the ore: the third how to reduce the separated metal to its simplicity and ductility: and the fourth to mix, work, gild, polish the metals, and imitate the finer metals in the coarser."

(q) See above, §. 21.

Account of Agricola.

(r) "George Agricola was born at *Glanbach*, a town of *Misnia*, in 1494, and died at *Chemnitz* in 1555. His works *de re metallica*, reprinted several times in folio, is a proof of the author's extraordinary learning and experience: by visiting all the mines, and conversing freely with the miners in Germany, he got a thorough knowledge of the whole process of metals; and from him most of the following writers have taken the greatest part of what they know. He wrote with the exactest fidelity, and in an

"elegant Roman style; so that we consult him in metallurgy upon all occasions."

"In the first part of metallurgy, or the discovery of metals, he is the only author; he describes with great accuracy and minuteness, all the arts and instruments made use of to discover mines, and to know whether in any given glebe, there be metal, and of what kind. Nor is he defective in any of the other parts. Several authors have wrote comments on him; but he is clear enough without any."

His Writings.

1. *De re metallica Lib. xii.* the best edition is that of *Frankfort*, containing a treatise *de re fodinaria* at the end. See below (9.)

2. *Bermannus, sive dialogus de re metallica.* Basf. 1530. 8vo. ab accurata autoris recognitione & emendatione nunc primum editus, cum nomenclatura rerum metallicarum. Lipf. 1546. 8vo. and Basf. 1549. 8vo. ap. *Froben*.

3. *De ortu & causis subterraneorum Lib. v.*

4. *De natura eorum quae effluunt ex terra, Lib. iv.* Ven. 1553. folio.

5. *De natura fossilium, Lib. x.*

6. *De veteribus & novis metallis Lib. ii.*

7. *Explication, in High-Dutch, of the terms used in metallurgy.* Basf. 1546. folio, and 1558. fol. The same, with the addition of a copious index: the whole revised, distributed into chapters, with the arguments of each chapter, and illustrated with marginal notes, by *Jo. Sigisfrido*. To which are added, observations upon metallic matters and names; from the papers of *Geo. Fabricius*; wherein chiefly those particulars are treated of, which *Agricola* had omitted. *Witteb.* 1612. 8vo.

8. *De animantibus subterraneis liber.* Basf. 1549. 8vo. and 1556. fol. ap. *Froben*.—in certa capita divisus, & nonnullis marginalibus exornatus, à *Jo. Sigisfrido. Witteberg.* 1614. 8vo.

9. *De re metallica Lib. xii. quibus officia, instrumenta, &c.* Twelve books on the subject of metals, wherein the houses, instruments, and machines, with every thing belonging to metallic affairs are copiously described, and represented to the eye by figures, inserted in their proper places, with the Latin and German names thereof. To which is added, the

H

same

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3. *Lazarus Erckern*, in his *Beschreibung aller fumemisten mineralischen ertz und bergwerks arten*, &c. *Francof.* 1694. under the Title of *Aula subterranea*, alias, *Probiere buch Lazari Erker* (s).

3. *Joan. Rudolph. Glauber*, thro' all his works, published at different times, and in various forms (t).

same author's book, *de animantibus subterraneis*, revised by himself. *Bas.* 1561. folio. To which in a posterior edition are added, *De animantibus subterraneis*, Lib. i. *De ortu & causis subterraneorum* Lib. v. *De natura eorum quae effluunt ex terra*. Lib. iv. *De veteribus ac novis metallis* Lib. ii. *Bermanus*, sive *de re metallica*. Lib. i. *Bas.* 1657. fol.

Account of Lazarus Erckern.

(i) " 1. *Laz. Erckern* was superintendant of the mines in *Germany*, *Hungary*, *Transylvania*, *Tirol*, &c. to three emperors; whence he was furnish'd with a compleat stock of metallic knowledge.

" 2. He is an experienc'd candid, and honest writer, relates nothing but what he had himself seen, without a word of theory or reasoning; and every where speaks as if he were sitting before the furnace, and relating what pass'd.

" 3. His way is thus: In *Hungary* there is such a mountain; wherein you have such an earth; beat, or grind it into powder, and wash it in water, and it will be of such a colour, and weight; and will contain so much gold, so much silver, so much copper. In such manner he teaches how it is to be burnt or roasted; what rules and signs are to be observ'd therein; how the fire is to be rais'd or diminish'd, &c.

" 4. He never fails enumerating every circumstance; and always in the most open artless manner, and a clear easy stile; adding figures for farther illustration; his book was wrote in *High-Dutch*, and printed in folio: and so much valued by the curious, that *Mr. Boyle* laments his not understanding that language, merely for the sake of reading this author. But it has been since translated into *Latin**, with excellent notes; so that this single work might almost suffice for the whole art of assaying."

5. The same work is translated into *English* under the title of *Flata minor*; or, *The laws of art and nature, in knowing, judging, assay-*

ing, sining, refining, and enlarging the bodies of confined metals. To which are added, essays on metallic words, illustrated with sculptures. By *Sir J. Pettus*, *London*. 1683. folio.—But the book deserv'd an abler translator.

Account of Glauber.

(t) " 1. *J. Rud. Glauber* was a celebrated chemist of *Amsterdam*, accounted the *Paracelsus* of his time. He had travell'd much, and by that means attain'd to a great many secrets. He wrote above thirty tracts; in some of which he acted the physician, in others the adept, and in others he metalist. He principally excell'd in the last; and yet, even here, he comes short of *Agri-*
colo and *Erckern*, in point of fidelity, simplicity and exactness; being ever forward to mix his own speculations and reasonings along with matters of fact.

" 2. He was a person of easy, genteel address; and beyond dispute well vers'd in chemistry; being author of the salt still extant in the shops under the title of *Sal Glauberi*; as also of all the acid spirits made by means of oil of vitriol, &c.

" 3. He is noted for extolling his arcana and preparations; and is even said to have traded a little unfairly with his secrets: the best of them he would sell at excessive rates to chemists, and others; and afterwards sell them over again; or make them public to increase his fame: whence he was continually at enmity with one or other.

" 4. It was this *Glauber*, who shew'd before the States of *Holland*, that there is gold contain'd in sand; and made an experiment thereof to their satisfaction: But so much lead, fire, and labour were employ'd in procuring it, that the art would not bear its own charge†. However, he shew'd pretty clearly, that there is no earth, sand, salt, sulphur, or other matter, but has its share of gold."

5. *J. Rud. Glauber* was born about the beginning of the sixteenth century: he labour'd

* We have not been so happy as to meet with this *Latin* translation, after a good deal of enquiry.

† *Dr. Stahl*, notwithstanding, thinks it might still turn to account; the process is very simple, and takes up little time. All they use in it is silver, sand, and litharge; and the silver does not waste in the operation, but is refined thereby.

bour'd greatly in the pharmaceutical and physico mechanical chemistry; made a multitude of experiments, which, if rightly understood and applied, might conduce very much to the knowledge of the composition and analysis of metals, sulphurs, and salts.

6. He spent his whole life in the exercise of chemistry; for the practice of which he excell'd all those of his age. But he rarely saw the use of his own experiments; applying passages of the ancient chemists to his own productions; and thence vainly pretending to the discovery of panaceas, the philosopher's stone, &c. he drew many into snares, and exposed the art to censure and reproach.

7. In his theory he is very confused; but whether in the practice he be guilty of so many falsehoods, as some have charged him with, may be much doubted: especially if we keep strictly to his experiments, without regarding the golden promises he makes.

His Works.

His writings are these:

1. *Furni novi philosophici*, &c. or, description of new methods of distillation, &c. in *High-Dutch*, I, II, III, IV, and V parts. *Amst.* 1648—1650. 8vo.

2. *Annotationes, über den appendixen*, &c. Annotations on the Appendix to the Vth part of the philosophical furnaces, containing several useful secrets, &c. *High-Dutch. Amst.* 1650, 1661.

3. *La description des nouveaux fourneaux philosophiques*, traduit par le Sieur du Teil, à Paris 1659. 8vo.—In *English*, by J. F. M. D. London 1651. 4to.

4. *Operis mineralis, oder vieler künstlichen*, &c. A description of several profitable metallic operations, &c. *High-Dutch*. I, II, III parts. *Francf.* 1651. 8vo. and 1655. 4to.

5. *Operis mineralis, pars I. ubi docetur*, &c. Wherein is taught, the method of separating gold from flints, sand, clay, and other soils, by spirit of salt. *Amst.* 1651.—Translated into *English* under the title of Glauber's golden art, to get gold from stones, sand, &c. 8vo.

6. ——— *Pars II. De ortu & origine*, &c. On the origin of all metals and minerals; how they are produced by the stars, assume a body from water, earth, &c. *Amst.* 1652. 8vo.

7. ——— *Pars III. in qua titulo commentarii*, &c. Wherein under the title of a commentary on Paracelsus's book called *cælum philosophorum*, or *tabula vexationem*, the transmutations of metals in general are delivered. *Amst.* 1652. 8vo.

8. *Gründliche, warbaffte beschreibung*, &c. A compleat account how to prepare tartar in great quantities from wine-lees, &c. *Nurinb.* 1652. 8vo.—In *Latin. Amst.* 1655. 8vo.

9. *Miraculum mundi, oder ausführliche beschreibung*, &c. A compleat description of the wonders of nature, art, and science, in the ancient universal menstruum, or *mercurius philosophorum*, &c. *High-Dutch. Hanau* 1653. 8vo.

10. *Pharmacopœa sagyrica, oder gründliche beschreibung*, &c. I, II, III, IV, V, VI, and VII parts. *Nurinb.* 1754. 8vo. and *Amst.* 1656—1667. 8vo.

——— In *Latin. Amst.* 1656. 8vo.

——— I, II, and III. Appendix to the same *High-Dutch, Amst.* 1667, 1668. 8vo.—The first part translated into *Latin. Amst.* 1669. 8vo.

11. *Des Teutsclands wolsahrt*, &c. The prosperity of Germany, part I. Concerning the concentration of wine, corn, and wood, &c. *Amst.* 1656. 8vo.

12. ——— II, III, IV, V, and VI. parts.

13. *Trost der Seefabrenden*, or consolation of sea-faring persons, *Low-Dutch. Amst.* 1657. 8vo.—In *Latin, ibid.* 1657. 8vo.

14. *Tractatus de medicina universali, seu auro potabili vero*. *High-Dutch. Amst.* 1657. 8vo.

15. *Opera chymica, Bücher und Schrifften*, &c. 1st part. *Franc. M.* 1658. 4to—11d part. *Francf.* 1658. 4to.

16. *Tractatus de natura salium* *High-Dutch.* 1658. 4to—In *Latin. Amst.* 1659. 8vo.

17. *Explicatio über mein miraculum mundi*. *Amst.* 1658. 8vo.

18. *Oeuvres minerales*, &c. à Paris 1659. 8vo.

19. *Ander Theil*, or second part of the *Mirac. mund.* *Amst.* 1660. 8vo.

——— *Continuatio. Amst.* 1657. 8vo.

20. *Reichen-Schatz und Sammel-Kasten*, &c. A rich treasure, &c. I, II, III, IV, and Vth centuries. *Amst.* 1660, and 1668. 8vo.—1st and 11d centuries in *Latin. Amst.* 1660, and 1661. 8vo.

21. *Libellus dialogorum. Amst.* 1663. 8vo.

22. *Explicatio, oder Auslegung*, &c. An explication of the words of Solomon, "in herbis, verbis, & lapidibus magna est virtus." *High-Dutch. Amst.* 1663. 8vo.—In *Latin. Amst.* 1664. 8vo.

23. *Libellus ignium, oder feuer-büchlein*, &c. A treatise of fires, &c. *High-Dutch. Amst.* 1663. 8vo.

24. *Novum lumen chymicum. High-Dutch. Amst.* 1664. 8vo.

——— In *Latin. Amst.* 1664. 8vo.

25. *Von den dreyen anfangen der metallen*, &c. Of the three principles of metals, sulphur, mercury, and salt. *Amst.* 1666. 8vo.

——— In *Latin. Amst.* 1667. 8vo.

26. *Kurtze erklärung über die Hölliche Göttin*, &c. Explication of the infernal goddess Proserpina, wife of Pluto; what the philosophical

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5. *Joachim Becker*, in his *Metallurgia*. Francof. 1660, 8vo (u).

philosophical poets, as *Ovid*, *Virgil*, and others mean by her; and how by *Proserpine's* help the souls of dead metals are deliver'd from the chemical hell, &c. *Amst.* 1667. 8vo.

27. *De tribus lapidibus ignium secretorum, oder von den drey alleredelsten gesteinen*, &c. Of the three precious stones produced by three secret fires. *Higb-Dutch. Amst.* 1667. 4to. and 1668. 8vo.

28. *De Elia artista*. *Higb-Dutch. Amst.* 1668. 8vo.

29. *De purgatorio philosophorum*. *Higb-Dutch. Amst.* 1668. 8vo.

30. *Glauberus concentratus, oder laboratorium Glauberianum*. *Higb-Dutch. Amst.* 1668. 8v.

——— *Oder kern der Glauberischen schriftten*, &c. The kernel of *Glauber's* writings, &c. in *Higb-Dutch. Lips.* and *Bresl.* 1715. 4to.—Translated into *Latin*, under the title of *Glauberus concentratus*.

31. *De igne secreto philosophorum*. *Higb-Dutch. Amst.* 1609. 8vo.

32. *De lapide animale*. *Higb-Dutch. Amst.* 1669. 4to.

33. *Curieuse tract von gebrauch*, &c. A curious tract on the use of wines, corns, and woods. *Higb-Dutch. Amst.* 1686. 4to.

34. His works, translated into *English*, by *Crist. Pack*. *Lond.* 1689. folio.

35. *Tractat. de signatura salium, metallorum, & planetarum*. *Higb-Dutch. Prag.* 1703. 8vo.

36. His whole works are translated into *Latin* in several vol. 8vo.

Account of *Becher*.

(u) *Jo. Joach. Becher*, of *Spire*, was born about 1625, and first made professor of physics, and then first physician to the elector of *Mentz*; and afterwards to the elector of *Bavaria*, and counsellor to the emperor. He was a man of great wit, as well as learning; and skill'd in all the parts of science: as appears by his numerous writings upon medical, philological, political, and mathematical subjects. But his chief application was to chemistry; of which he made great use in illustrating natural philosophy, and discovering the principles and composition of bodies. He lived some time in *England*, and died at *London* in 1682.

2. He appears to have been a warm, active, industrious man, and a little too much ting'd with alchemical notions; but was almost the first author who applied chemistry to philosophy at large, and shew'd its extensive uses in explaining the structure, texture, composition, and relations of bodies.

* *V. Rosb. Scholtz. Bibl. Chemic.* p. 91. 122.

3. His theory is by many prefer'd to that of all other chemists, as sounder and deeper. He deduces all things from water and earth, as the only material principles. The earthy principle he shews to be of three kinds; that is, he makes three species of elementary earths. This he chiefly effected in his *physica subterranea*, where he has shewn great acuteness, in applying the principal and known experiments to the framing a theory in the way of experimental reasoning.

His Chemical Writings.

His chemical works are chiefly these:

1. *Institutiones chemice, seu manuductio ad philosophiam hermeticam*. *Mogunt.* 1662. 4to.—The same with notes, and other improvements, publish'd by *J. Jac. Rosenstengel*. *Franc.* 1705. 12mo. and 1716. 8vo.

2. *Oedipus chemicus, obscuriorum terminorum, & principiorum chemicorum mysteria aperiens & resolvens*. *Amst.* 1664. 12mo.

3. *Actorum laboratorii chymici monacensis, seu physice subterraneae libri ii*. Transactions in the chemical laboratory at *Munich*, or subterranean physics, in two books. *Franc.* 1669. 8vo. *Lips.* 1681. 8vo.—The same, with supplements from the author's other writings, collected by *G. Ern. Stahl*. *Lips.* 1703. 8vo.

4. *Experimentum chymicum novum, quo artificialis & instantanea metallorum generatio & transmutatio ad oculum demonstratur*. *Franc.* 1671. 8vo. Also at the end of the *physica subterranea*.

5. *Demonstratio philosophica, seu theses chymicae, veritatem & possibilitatem transmutationis metallorum in aurum evincentes*, &c. *Francof.* 1675. 8vo. Also printed at the end of the *physica subterranea*.

6. *Experimentum novum & curiosum de minera arenaria perpetua*, &c. 8vo. *Lips.* 1680. Also in the *physica subterranea*.

7. *Tripus hermiticus fatidicus, pandens oracula chymica*; seu, (1). *Laboratorium portatile*. (2) *Nitri & salis textura anatomia*. (3). *Alphabetum minerale, seu viginti quatuor theses de subterraneorum & mineralium generis, textura, & analyse*, &c. *Francof. M.* 1689. 8vo*.

8. *Concordantia chemica*, in *Higb-Dutch*, 4to. Not translated into *Latin* that we know of. It contains many insignificant and useless processes; but at the same time many curious and useful experiments.

9. *Metallurgia, oder natur kundigung der metallen*, or the physiology of metals. *Higb-Dutch*.

6. *Joan. Kunkel*, in his *Philosophia chimica experimentis confirmata*. Amstelod. 12mo. 1694 (x).

7. *Olaus Borrichius* in his *Docimastica metallica*. Hafniæ, 1660, 8vo, & 1677, 4to, & 1680, 4to (y).

CLASS III. Alchemical Writers.

In the alchemistic Branch the most approved authors are,

1. *Geber*, whom nevertheless *Bernard*, Count of *Trevisa*, ranks among the sophistical authors. authors in alchemy.

2. *Morienus*.

3. *Roger Bacon*.

4. *George Ripley*.

5. *Raymund Lully* (z).

Account of Kunkel.

(x) *Jo. Kunkel*, born about the year 1630, was first bred up to pharmacy, then to glass-making; he was afterwards chemist to the elector of Saxony, then to the elector of Brandenburg, and lastly to the king of Sweden. He applied himself to chemistry upwards of fifty years; whereby he arrived at a pitch of experience seldom met with. Having the advantage of his patrons purses for trying all manner of experiments, besides being master of the glass-works, he had opportunities of making the most tedious experiments without charge: Withal he was very industrious, preserving, and acute in noting the phenomena of processes. But for the theoretical part he was less happy; as not being versed in philosophy and general knowledge. His doctrine of principles is fluctuating and defective. He allowed not of sulphur in that quality: into which opinion he seems to have been led by *Jf. Hollandus*.

His writings are these; viz.

1. *Observationes chemiæ*, first published in High-Dutch, 1676, and translated into Latin under this title, *Johannis Kunkelii elect. Sax. cubicularii intimi & chymici, utiles observationes, sive animadversiones de salibus fixis & volatilibus, auro & argento potabili, spiritu mundi & similibus. Item de colore & odore metallorum, mineralium, aliarumque rerum quæ in terra producuntur, &c.* Primum ab autore Germanice conscripta, nunc vero Latinitate donata à *Carolo Aloisio Ramsais*. Londin. & Rotterodam 1678. 12mo.

— The same, under the title of *philosophia chemica, experimentis confirmata*. Amst. 1694. 12mo.

2. *On phosphorus*, High-Dutch. Lips. 1678. 8vo.

3. *De acido & urinoso, sale calido & frigido, &c.* Berl. 1686. 8vo.

4. *Art of glass*, or commentary on *Ant. Neri*, in High-Dutch. Franc. and Lips. 1689. 4to. A curious work, which we expect to see soon publish'd in English, by a very able hand.

5. *Collegium physico-chymicum experimentale; sive laboratorium chymicum, &c.* Hamb. & Lipsic. 1722. 8vo. High-Dutch. A posthumous work.

Account of Borrichius and his writings.

(y) *Olaus Borrichius* was born in 1626. He was physician to the king of Denmark, and public professor in the university of Copenhagen. He had travell'd much, was an excellent scholar, and a great operator in chemistry. He is famous for the dispute he held with the learned *Conringius*, concerning the knowledge of the Egyptians, and the antiquity of chemistry, its inventors and authors. His writings, besides that above-mention'd, are chiefly those so often quoted in this work, viz.

1. *De ortu & progressu chemiæ dissertatio*. Hafn. 1668, 4to. And in *Mangeti Bibl. Chym.*

2. *Ol. Borrichii, Hermetis, Ægyptior. & Chemicor. sapientia, ab Herm. Conringio, animadversionibus vindicata*. Hafn. 1669. 4to.

3. *Conspectus scriptor. chemicor. illustr. libellus posthumus*. Haun. 1697. 4to. and in *Mavg. Bibl. Chym.*

For other pieces of his, see the *Act. Hafn.* See also,

4. *Herman. Conringii de hermiticâ medicinâ, libri duo, quorum primus agit de medicinâ, pariterque omni sapientiâ veterum Ægyptiorum: altero non tantum Paracelsi sed etiam chemicorum Paracelsi laudatorum, aliorumque potissimum quidam medicina omnis, simul vero & reliqua doctrina examinatur*. Helms. 1648. 4to. A second edition, corrected and enlarged with an apologetic against *Borrichius*. 1669. 4to.

(z) For the characters and writings of these five authors, see above §. 22, 24, 25, and 27.

The History of CHEMISTRY.

62. (6) Bernard count of Trevisa; who wrote in the year 1453 (a).
 63. (7) Joan. Isaac Hollandus, who perhaps was the same with the (b) following.
 64. (8) Isaac Hollandus, who was posterior to Arnoldus de la Villa nova, but earlier than Paracelsus. He was so highly esteemed by Penotus, that (being discovered in some corner, in Paracelsus's time) he took him for Elias, the promis'd artist, who is to reveal the secrets of chemistry (c).
 65. (9) Basil Valentine, (d) in his *Chymische schriften*. Hamburg, 1694, 8vo (e).
 66. (10) Artephius (f).
 67. (11) *Theatrum chymicum* (g).
 68. (12). *Turba Philosophorum* (h).
 69. (13) Paracelsus (i), See his *opera omnia*, Lat. Genev. 1658, 2 vol. Fol.—In *Higb-Dutch*, Straßb. 1603, 2 vol. Fol.—In *Higb-Dutch*, Straßb. 1616, 2 vol. Fol.
 70. (14) Irenæus Philaletha (k).

71.

Account of Bernard of Trevisa.

(a) Bernard count of Trevisa, flourished about the year 1309; and was intimate with Thomas Bononiensis, first physician to Charles the VIIIth king of France: to whom he wrote an alchemical epistle*.

(b) (c) Vid. *Libaw. Alchim. Pharmaceut.* p. 122.

(d) For the character of these three authors see above, §. 29, 30.

(e) Also *Hamburg*, 1677. 8vo. *ibid.* 1717. 8vo. with figures.

(f) *Artephius* and *Morienus* are usually supposed prior to Roger Bacon; but the age, or even country, where they lived is not known. The former is firmly believ'd by the adepts to have prolong'd his life to a thousand years†.

(g) *Theatrum chemicum in sex vol. divisum.* Argent. 1613, 1622, 1661. 8vo. A list of the pieces contain'd in the several volumes of this collection, being one hundred twenty-three in number, is given in *Endteri Catal.* *Libror. Med. Phys. Mathem. Norib.* 1695. 4to. p. 137—140.

(h) *Turba philosophorum, sive auriferæ artis antiquissimi auctores.* iii. vol. 1510, 1562, 1610. 8vo. In it are contain'd thirty-two pieces, a

list of which is given in *Endter, ubi supra.* p. 144.

(i) See an account of him and his writings above p. 37—40.

Account of Irenæus Philaletha and his Works.

(k) There are several alchemical books published under the name of *Philaletha*; the first anonymous *Philaletha* is said to have been an Englishman and his true name *Thomas Vaughan*; tho' in some of his works he calls himself *Irenæus*, and in others *Eugenius Philaletha*. He is famous for having render'd *Van Suchten*, *Sendiwogius*, and *d'Espagnet* clearer, in his writings; which are chiefly these: 1. *Introitus apertus ad ocellum regis palatium.* 2. *Breviis manducatio ad Rubinum caelestem.* 3. *Fons chemicæ veritatis.* 4. *Metallosum metamorphosis.* 5. *Vade mecum philosophicum.* 6. *Experimenta de preparatione mercurii philosophici.* 7. *Nucleus alchemicæ.* But tho' this author is said to write with great clearness, yet his followers differ widely from one another. See also,

8. *Eug. Philalethes, Euphrates*, or the waters of the east, treating of the secret fountain whose water flows from fire, and carries in it the

* See *Junker. Confp. Chem.* p. 17. See also *Bern. Com. Trevisa de chymico miraculo quod lapidem philosophicæ appellant.* *Dionys. Zacharias Gallus de eodem: Cum annotationibus Nicolai Flamelli, auctoritatibus variis principum hujus artis, Democriti, Geberi, Lullii, Villanovani, confirmata & illustrata, per Gerard. Dorneum.* Bas. 1600 8vo. *ibid.* 1583. 8vo. Vid. *J. Rothscholtz Bibl. Chem.* p. 26. seq. This is also extant, under the title of, *Nicolai Flamelli annotationes chymicæ ex Democrito, Gebero, &c.* printed in the *Theat. Chym. Ursell.* Tom. I. p. 848. In *Manget's Bibl. Chym.* p. 350. We find the same under the title of *Nicolai Flamelli Galli, commentarius in Dionysii Zacharii opusculum chymicum.* Vide *Rothscholtz. Bibl. Chym.* p. 79.

† *Junch. Confp. Chem.* p. 16.

71. (15) *Michael Sendivogius (I)*:
 72. (16) *John Baptista van Helmont; opera omnia.* Amstelod. 1652, 4to (m).

CLASS IV. Chemical Improvers of Natural Philosophy and Physic.

73. Among the writers who have treated of chemistry with a view to natural philosophy and medicine, the chief are these;

Writers in
philosophical
chemistry.

1. The same *Helmont*.
2. The honourable *Robert Boyle Esq*; thro' all his writings (n).

the beams of the sun and moon. London 1665. 8vo.

9. *Anima magica abscondita*: or a discourse of the universal spirit of nitre; with the strange abstruse miraculous ascent and descent: published together with his *Anthroposophia magica*. London 1656.

10. Secrets reveal'd, or an open entrance to the shut palace of the king; containing the greatest treasure in chemistry, by *Irenaeus Philalethes, Cosmopolita*; who attain'd to the philosopher's stone, aged twenty-three years. Published by *W. C. Esq*; London. 1669.

11. *Enarratio methodica trium Geberi medicinarum, in quibus continetur lapidis philosophici vera constructio.* Amst. 1678. 8vo.

12. A collection of ten treatises in chymistry, concerning the liquor alkahest, the mercury of the philosophers, and other curiosities; written by *Irenaeus Philalethes, Helmont, &c.* Lond. 1684. 8vo*.

Account of Sendivogius.

(I) *Sendivogius* was companion to *Alexand. Sidonius*, or *Serenus*, a Scotch gentleman, who being near the point of death, intreated two things of him: to take care of the publication of his MSS; and to marry his widow. *Sendivogius* perform'd both; but in the edition of his works, suppress'd *Serenus's* name and clapp'd his own in it's place. The titles of his pieces are,

1. *Novum lumen chemicum.* A new chemical light.

2. *Dialogues de mercurio & alchemia.* A dialogue of mercury and alchemy.

In these he maintains, with great strength of reason and experiment, that sulphur and mercury united, are the constituents of every metal; by sulphur meaning with *Geber* the sun's rays: however, his writing should be read with caution; being full of vain promises. His *novum lumen chemicum* is done into English, and entitled *A new light of alchemy, from nature and manual experience: with a treatise of sulphur.* To which are, added nine books of the nature of things, by *Phil. Theoph.*

Parac. English'd by *J. F. M. D. Lond.* 1674. 8vo.

(m) *Van Helmont opera medica.* 1682. 4to containing 118 different pieces†.

Account of Mr. Boyle.

" (n) 1. The honourable *Robert Boyle Esq*;
 " that prodigy of knowledge, excels not less
 " as a chemist, than as a natural philosopher.
 " His character is one of the most amiable
 " in the world: no body ever made more ex-
 " periments, or with more care and caution
 " than he; nor does any body relate the e-
 " vents thereof with greater candour and fi-
 " delity. He is ever wary and reserved in
 " drawing conclusions from his experiments;
 " and rarely concludes too much. He held
 " a very amicable correspondence with all
 " the chemists, and other virtuosi of his age;
 " and thus effected a kind of commerce, or
 " communication of secrets. Add, that he
 " was always perfectly frank in imparting
 " what he had learnt, or discover'd, to the
 " public.

" 2. He gives abundance of good things
 " relating to *fossils*, their origin, separation,
 " preparation, purification, and the ways of
 " fitting them for human uses; and the same
 " he has done with respect to *vegetables*: but
 " he is chiefly to be admir'd for what relates
 " to *animals*, and the analysis of their parts;
 " in which he follow'd the path trod by *Hel-*
 " *mont*, in his book *de libiâsi*. A noble in-
 " stance hereof we have in his history of hu-
 " man blood; which contains many most va-
 " luable and exquisite things; and on every
 " occasion he endeavours to found his rea-
 " sonings on experiments. His treatises of
 " the unforeseen failure of experiments, and
 " sceptical chemist, shew his great modesty and
 " moderation; and how far he was from that
 " common vice of the chemists, boasting, and
 " promising more than he could perform.

" 3. He is author of a vast number of
 " pieces, all compos'd in the same spirit.
 " They are so many, and printed so sepa-
 " rately

* See *Wood's Athenæ Oxon.* T. 2. p. 368.

† *V. Endter. Catal.* p. 62. seq.

3. Jo. Bohnius, in his *Dissert. chimyco-physica*. Lips. 1696 (a).
4. The celebrated Dr. Cox (p) and Dr. Slare (q) in several papers in the *Philosoph. Transact.*
5. M. Homberg (r), Geoffroy (s), and the younger Lemery (t) in the memoirs of the royal academy of sciences.

6.

“rately, that it is exceedingly difficult to procure a compleat collection. His style is a little loose and diffusive; and the course of his writings sometimes interrupted with digressions, and particularities not very essential*.”

“4. One objection is made to him in his chemical character, viz. that taking the virtues of his preparation on the report of other people, he commends some of them too much, and attributes virtues to them which experience does not warrant. For, as he did not practise physic himself, his way was, upon making any new preparation, to give it some physicians to make trial thereof; and they, it seems, out of complaisance, would speak more largely of it than it deserv'd. Hence those profuse commendations he bestows on the spirit of human blood and hart's-horn in pleuritic and phtisical cases, and on the *ens Veneris* in the rickets.

“5. As to the point of credulity commonly charg'd on Mr. Boyle, there does not seem to be any foundation for it; no body enquires into things more severely, or speaks of them more dubiously than he. Indeed, a long, and intimate acquaintance with the writings of Paracelsus and Helmont might possibly have some effect on the bent of his mind; and induce him to give too much credit to many of the *arcana* they pretend to: and the more so, considering the great number of strange incidents and events which had fallen within his own observation.”

(o) “John Bohn was professor at Leipzig in 1679: the dissertations above-cited, besides an uncommon reading, shew that he had made a large number of experiments. And as to his reasonings no body goes beyond him. His treatise *de acido & alkali* is excellent; and has let much light into the affair.”

Account of Dr. Cox's Papers.

(p) Dr. Daniel Cox, an eminent physician, and very able chemist, has wrote some curious papers, tending to improve the art of chemistry; the principal of which are the following, to be found in the *philosophical*

transactions; viz. 1. On the pre-existence of alcalizate or fix'd salt in any subject before its being exposed to the fire; shewing also that alcalizate salts do not differ from each other. *Phil. Transf.* N° 107. p. 150. 2. Of the volatile spirit and salt of vegetables. *Phil. Transf.* N° 101. p. 4. 3. The identity of all volatile salts and vinous spirits: with two experiments of vegetable salts, perfectly resembling the shape of the plants, whence they had been obtain'd. *Phil. Transf.* N° 108. p. 169.

Account of Dr. Fred. Slare's Papers.

(q) Dr. Fred. Slare, another eminent physician and chemist, has wrote several small pieces upon chemical subjects, viz. 1. Experiments made with the liquid and solid phosphorus. *apud Hook. Phil. Collect.* N° 3. p. 48. 2. A continuation of the same. *ibid.* N° 4. p. 84. and *Phil. Transf.* 1685. 3. On the accension of fluids, *Phil. Transf.* N° 150. p. 289. 4. Examination of stones from the human body. N° 182. p. 140. 5. Of fire, flame, and explosion, by mixing two cold liquors, N° 213. p. 201. 6. Experiments of accension and explosion in *vacuo*. *ibid.* p. 212. 7. Experiment on the change of colour, from a pale, transparent, or clear liquor, to a very blue one in an instant, by the admission of the air only. N° 204. p. 898. 8. Examination of chalybeate or Spaw-waters, called *acidule*; proving them to be alkaline. N° 337. p. 247. 9. On the nature and virtues of Pyrmont-waters. N° 351. p. 564. 10. Experiments and observations on Bezoar-stones; with a vindication of sugar. *London*. 1715. 8vo. and *Phil. Transf.* N° 337. p. 273.

Account of M. Homberg.

(r) 1. M. Homberg was born at Batavia, in the East-Indies, in 1652; whence he came over, with his father, to Amsterdam. He was sent to Jena and Leipzig to study law; but neglecting this for what was more agreeable to his genius, he applied himself to Otto Guericke, famous for the invention of the air-pump, the hemispheres, &c. to learn experimental philosophy.

2. From hence he went to Padua, where he spent a year in the study of medicine, and particularly anatomy and botany. Afterwards

* In the late abridgment of his works in three volumes in quarto, 'tis to be hoped all these inconveniences are removed.

thwards he travell'd to *Bologna* and *Rome*; hence pass'd into *France*, and thence into *England*, where he work'd some time with the great Mr. *Begh*. From *England* he went to *Holland*, where he perfect'd himself in anatomy under the famous *De Graeff*, and lastly, took the degree of doctor of physic at *Wittembourg*.

3. Afterwards he made a tour thro' *Germany* and the north; and likewise through *Saxony*, *Bohemia*, *Hungary*, and *Sweden*, to view the mines. At *Stückholm* he staid some time, and work'd in the king's laboratory. His next remove was into *Holland*, and thence into *France*, to pick up what had before escap'd him.

4. From *Paris*, at the earnest desire of his father, he was upon the point of returning to *Saxony*, to settle among his friends: but M. *Colbert* sending a messenger to him in the king's name, with very advantageous offers to settle there, he accepted them after a short deliberation, and commenced Catholic in 1682.

5. In 1685 he went to *Rome*; and practis'd physic there, with good success: but in a few years he return'd to *Paris*; and in 1691 was chose a member of the royal academy, and put in possession of its laboratory. In 1702 he instructed the duke of *Orleans* in chemistry; the most magnificent and best appointed laboratory which chemistry had ever known, being provided for this purpose. The same year his Highness procur'd M. *de Tschirnhausen*'s large burning-glass from *Germany*, of which M. *Homburg* made a noble use. He married a daughter of the famous *Dodart* in 1706; and in 1715 died of a dysentery.

6. He never publish'd any express work, or volume in form: His *essays*, or *elements of chemistry* were begun to be printed in the memoirs of the academy; and the rest of them were found fit for the press at his death. There are likewise several lesser pieces on various subjects, dispers'd throughout the same memoirs: none of which but open new views, and shine with their peculiar light. His way of expressing himself was simple, precise and methodical; and he was as far from the natural ostentation of the chemists, as from their mysteriousness and obscurity.

"7. M. *Homburg* was a most expert and masterly chemist. He has distinguish'd himself by a great number of general experiments, as well as by his reasonings; which are always perfectly fine and clear, and conducted with mathematical severity. Natural philosophy would have receiv'd considerable improvement from him, had his life been continued. He was a person of great genius, profound skill, and indefati-

gable industry: he was supported by the duke of *Orleans*, late regent of *France*; and perform'd experiments at his expence; which gave him an opportunity of trying many things out of the reach of a private person."

His Writings.

Many of his pieces are only given in extract by M. *Fentenille* in the history of the royal academy.

His other chemical writings are the following:

1. The method of making the phosphorus ardens of *Kunkel*. *Mém. de l'Acad. Royale des Sciences*. an. 1692. p. 101.
2. Experiments on phosphorus. *ib.* p. 133.
3. On metalline vegetations. *ib.* p. 209.
4. A method of extracting a volatile acid salt in a dry form. *ib.* p. 253.
5. On the infusion of antimony. *ib.* an. 1693. p. 217.
6. A new phosphorus. *ib.* p. 270.
7. On an extraordinary event in cupelling gold. *ib.* p. 240.
8. On the quantity of acid salts in different acid spirits. *ib.* an. 1699. p. 69.
9. On examining the salts of plants. *ib.* p. 101.
10. On the quantity of acids absorb'd by terrestrial alkalies. *ib.* an. 1700. p. 81.
11. On the dissolvents of mercury. *ib.* p. 245.
12. On the oils of plants. *ib.* p. 266.
13. On the acid of antimony. *ib.* p. 381.
14. On the refining of silver. *ib.* an. 1701. p. 52.
15. On the effects of fermentation. *ib.* p. 124.
16. On the analyses of plants. *ib.* p. 143.
17. On the volatile salts of plants. *ib.* p. 288.
18. Chemical essays on the Principle salt. *ib.* 1702. p. 43.
19. Attempt to analyse common sulphur. *ib.* 1703. p. 36.
20. On a medicated cup from *Siam*. *ib.* p. 62.
21. On the principle sulphur. *ib.* an. 1704. p. 117.—The sequel of the same. *ib.* an. 1706. p. 127.
22. On a dissolution of silver. *ib.* an. 1706. p. 127.
23. On the vitrification of gold by the burning-glass. *ib.* an. 1707. p. 50.
24. On acids and alkalies. *ib.* an. 1708. p. 403.
25. Chemical essay on mercury. *ib.* vx. 1709. p. 133.
26. Of the effects which certain acids have on volatile alkalies. *ib.* p. 463.

27. On sulphureous matters. *ib. an. 1710.*
 p. 301.
 28. On artificial vegetations. *ib. p. 556.*
 29. On the fecal matter. *ib. an. 1711.*
 p. 49. Continuation of the same. *ib. p. 307.*
 30. On the colour of bodies in fusion. *ib.*
 p. 21.
 31. On acids in the blood of animals. *ib.*
an. 1712. p. 9.—The sequel of the same.
ib. p. 349.
 32. On a separation of gold from silver by
 fusion. *ib. an. 1713. p. 87.*
 33. On a sublimation of mercury. *ib. p. 354.*
 34. On matters which penetrate metals,
 without dissolving them. *ib. p. 409.*
 35. On the vegetation of the fix'd salts of
 plants. *ib. an. 1714. p. 240.*

Account of Dr. Geoffroy.

(1) 1. *Steph. Franc. Geoffroy* was born at *Paris* in 1672. His father was an apothecary, and his mother a surgeon's daughter. His father spar'd no pains nor expence in his education; tho' he design'd him only for the shop; as well knowing that a large share of knowledge was required to arrive at any tolerable perfection in pharmacy. To the study of philosophy in general, *M. Geoffroy* join'd private courses of botany, chemistry, and anatomy.

2. In 1692 his father placed him with an eminent apothecary at *Montpelier*; and during his stay there he diligently attended the university lectures, in all the branches of medicine; but the *materia medica* was his favourite study. In 1693, he pass'd through the usual examination for pharmacy, with applause; and now first imparted to his father his design of being a physician; and obtain'd his consent. Accordingly, the second son, whom his father had design'd for that profession, was sent into the shop, instead of his brother; and is now one of the chemists to the *French academy*.

3. In 1698, *Count Tallard* being appointed ambassador extraordinary to *England*, took *M. Geoffroy* with him, as his physician. tho' he had then taken no degree in physic. There he became acquainted with many of the learned men of that nation, and neglected no means of making improvements; and in less than six months he was admitted a member of the royal society. From *England* he pass'd into *Holland*; and in 1700 travelled into *Italy* with the *Abbé Lavois*, in quality of his physician: every where making farther observations, and increasing his stock of knowledge. In 1699 he was made a member of the royal academy of sciences; and in that capacity con-

tributed, as far as his other employments would allow, to its ornament and use.

4. In 1702, he took his degree of bachelor of physic, and in 1704 that of doctor, at *Paris*: after which he applied himself closely to his studies, the better to fit him for practice. In 1707, *M. Fagon*, physician to the king, made him his deputy, as professor of chemistry in the royal garden; in which he acquitted himself so well, that in 1712 *M. Fagon* resign'd the charge up to him.

5. In 1709, the king made him physic-professor in the college royal; and here he dictated his curious and useful lectures on the *materia medica*. In 1718 he drew up a system, or table of the mutual relations betwixt different substances in chemistry; which, if rightly understood, and carried on, might become a fundamental law for chemical operations, and guide the operator with success.

6. In 1726, he was elected dean of the faculty of physic at *Paris*; and after the expiration of two years, the usual time of holding that office, was continued in it by the unanimous consent of his brethren. In the beginning of the year 1730 his health began to decline, and he died on the 6th of *January*, 1731.

His Writings.

His writings are these; *viz.*

1. On cold dissolutions and fermentations. *Mem. de l'Acad. R. des Sciences. an. 1700.*
 p. 142.
2. A method of recomposing sulphur. *ib. an. 1704. p. 374.*
3. A chemical problem to find ashes without iron in them. *ib. 1705. p. 478.*
4. Analysis of sponge. *ib. 1706. p. 660.*
5. Explanation on the artificial production of iron. *ib. 1707. p. 224.*
6. On the analysis of coral, &c. *ib. an. 1708. p. 130. and 482.*
7. Experiments on metals. *ib. an. 1709. p. 205.*
8. Observations on vitriol and iron. *ib. an. 1713. p. 225.*
9. On the conversion of acid salts into volatile urinous alcalies. *ib. an. 1717. p. 291.*
10. Chemical affinities between different substances. *ib. an. 1718. p. 256. and 1720. p. 24.*
11. A method of stopping the vapours of metalline dissolutions, &c. *ib. an. 1719. p. 93.*
12. Frauds relating to the philosopher's stone. 1722. p. 81.
13. On the method of extinguishing fire by means of gun-powder. *ib. an. 1722. p. 211.*

6. George Ernest Stahl, in his *Fundamenta chymie*. Norimberg. 1723, 4to (u).

7.

14. Examination of the waters of Passy. 1724. p. 287.

15. Experiments on some sorts of glass, of which bottles are made. 1724. p. 547.

16. On the mineral waters of St. Amand. *Phil. Transf.* No. 247. p. 430.

17. The way to make two clear spirituous inflammable liquors, which differ very little in taste and smell, yet being mix'd together, produce a fine carnation colour. *Phil. Transf.* No. 249. p. 4.

18. On the exact quantity of acid salts contain'd in acid spirits. *ib.* No. 262. p. 530.

19. A treatise of the fossil, vegetable, and animal substances, that are made use of in physic, &c. translated from a manuscript copy of the author's lectures read at Paris, by G. Douglas, M. D. 1736.

The writings of the younger M. Geoffroy, yet living, are these.

1. On essential oils. *Mem. de l'Acad. R. des Sciences.* an. 1707. p. 1686. and 1721. p. 193.

2. On the different degrees of heat, which spirit of wine communicates to water upon mixture. *an.* 1713. p. 69.

3. On gum lacca, and other animal substances, which furnish the purple dye. 1714. p. 156.

4. On oil of aspic, and the choice of it. *an.* 1715. p. 321.

5. A method of determining the just quantity of spirit of wine in inflammable liquors or brandies. 1718. p. 46.

6. On the nature and composition of Sal Ammoniac, &c. &c. 1720. p. 245.

The Writings of M. Lemery the younger, still alive.

(i) 1. Chemical experiments and observations on iron and the load-stone. *Mem. de l'Acad. R. des Sciences.* an. 1706. p. 448.

2. That plants really contain iron. *ib.* p. 529.

3. New experiments on oils, &c. *ib.* an. 1707. p. 6.

4. Reflections on a chemical vegetation of iron, &c. *ibid.* p. 388.

5. Explication of the composition of several kinds of native vitriols. *ib.* p. 713.

6. New remarks on the pretended artificial production of iron. *ib.* an. 1708. p. 482.

7. Conjectures and reflections on the matter of fire, &c. *ib.* an. 1709. p. 520.

8. On chemical precipitations. *an.* 1711. p. 72.

9. Conjectures on the different colours of the precipitates of mercury. *an.* 1712. p. 66. The second part. *an.* 1714. p. 336.

10. On the manner wherein iron operates on the fluids of the body. *an.* 1713. p. 41.

11. On the action of salts upon several inflammable matters. *an.* 1713. p. 130.

12. On matters proper for making a phosphorus with alum. *an.* 1714. p. 520.

13. Physical reflections on a new phosphorus. *an.* 1715. p. 30.

14. Memoirs on nitre. *an.* 1717. p. 39. Sequel of the same *ib.* p. 156.

15. On the volatilization of fix'd salts. *ib.* p. 317.

16. Reflections on the deficiency and small use of chemical analyses of plants, &c. *an.* 1719. p. 227. Second part of the same, *an.* 1720. p. 121. —Third part, *ib.* p. 216. —Fourth part. *an.* 1721. p. 28.

17. On the preparation of the Caribushan's powder, or kermes mineral. *an.* 1720. p. 542.

18. On the original of Sal Ammoniac. *an.* 1720. p. 66.

19. On the successive dissolution of different salts in water. *an.* 1722. p. 479.

Account of Stahl.

(u) G. Ern. Stahl, born in 1660 at Onold in Franconia, took to the study of chemistry at fifteen, and from reading Barnerus's *colligium chemicum*, readily discover'd a fix'd alkaline body in nitre: with the help afterwards of Kunkel's books, and Becher's *physica subterranea*; the several experiments of which he not only carefully weigh'd and compar'd, but repeated; he arrived at a great proficiency in the art, and has publish'd several excellent pieces on chemistry; which shew, among other things, 1. The generation of artificial sulphur. 2. The analysis of vitriol, the volatilization of the acid of vitriol, and its restitution to its pristine fixity. 3. The presence and influence of a phlogiston in several bodies. 4. The resolution of sulphur into a subtile acid. 5. The different fixity of acid mineral salts. 6. The sudden destruction of nitre by deflagration. 7. The genuine foundation of vinous and acetous fermentation. 8. The conversion of spirit of wine; and its artificial ingress into vinegar. 9. The transposition of juice of citrons into wine. 10. The passage of all fermentable bodies into an insipid earth. 10. The solution of gold by sulphur. And, 11. Of iron by an alkali, &c. &c.

The History of CHEMISTRY.

7. The excellent *Frideric Hoffman* (x), in his *Observationum physico-chymicarum selectiorum libris tribus*. Halæ, 1722, 4to. A work of great importance to the art of chemistry. The author has likewise enrich'd physic and medicine with many other curious pieces.

His principal chemical Writings.

1. *Prodromus de indagations chymico-physiologica*, &c. 1683.

2. *Collegium chemicum*, first deliver'd in 1684 in the way of lecture to the students at *Jena*; several manuscript copies of which getting abroad, and there being nothing like it then extant, many used it as a comment on *Becher*; this at length induced the author to consent to an edition of it, which was published under the title of, *Fundamenta chymie dogmaticæ & experimentalis*. Norimb. 1723.

— The same in *English*, under the title of *philosophical principles of chemistry*, &c. by *P. Shaw*. 1738. 8vo.

3. *Zymotechnia fundamentalis*. 1697.

4. *Observationes chymico-physicæ*. 1697, and 1698.

5. *Dissert. de metallurgiæ & docimasie fundamentalis*. 1697.

6. *Animadversiones ad artem tinctoriam fundamentalem & experimentalem*.

7. *Opusculum chymico-physico-medicum*. Halæ Magdeb. 1715. Consisting of several pieces that had been occasionally publish'd before:

viz. 1. *Prodromus de indagations chymico-physiologica*. 2. *Zymotechnia fundamentalis*. 3. *Observationes selectiores physico-chymico-medice*. 4. *Experimentum novum, verum sulphur arte producendi*. 5. *Spiritus vitrioli volatilis in copia parandi fundamentum & experimentum*. 6. *Vitulus aureus*, &c.

8. *Specimen Becherianum*, annex'd to *Becher's physica subterranea*.

9. *Dissert. de elogiis vitrioli*.

10. *A treatise on sulphur, both inflammable and fix'd*. In *High-Dutch*. 1718.

11. *A treatise on salts*. *High-Dutch*. 1723.

12. *Commentar. in metallurgiam Becheri*. 1723.

13. *Præf. in concordantiam chemicam Becheri*. 1726.

14. *Experimenta, observationes, animadversiones*, 300 numero, *chymicæ & physicæ, quantum alibi, vel nulla, vel rara, nusquam autem satis ampla, ad debitas usus, & veros usus, deducta mentio, commemoratio, aut explicatio, invenitur*, &c. *Berolin*. 1731. 8vo.

Account of Dr. Hoffman.

(x) *Frid. Hoffman* was born at *Hall* in *Saxony*, in 1660. To him we are chiefly indebted for a just method of analysing mineral waters. He first discovered the errors of the ancients on this subject, and shew'd the true ingredients of waters by chemical experiments. The chief points are, that the predominant salt in *acidule*, as well as in hot springs, is not acid, but alkaline: that neutral salts, called carious earths, and irony matters, with a most subtle volatile universal acid, are contain'd in all mineral waters. See his *Dissertationes de thermarum & acidularum usu ac abusu*; with others on the same subject; all which are abridg'd and publish'd in *English* by *P. Shaw*. 1733. 8vo.

His other chemical writings are these:

1. *Dissertationes de generatione salium*.

2. ——— de *nitri natura*.

3. ——— de *cinnabari antimonii*.

4. ——— de *mirabili sulphuris antimonii fixati efficacia*.

5. ——— de *mercurio, & medicamentis mercurialibus*, &c.

6. *Adnotationes & additamenta in Poterii opera*. *Franc. M*. 1698. 4to.

7. *Observationum physico-chymicarum select.* lib. iii. *Hal. Magd*. 1736. 4to.

APPENDIX TO THE CHEMICAL AUTHORS.

Some books of consequence being omitted by the author, or having been publish'd since he wrote, we judge it proper to add such of them as readily occur, and contain any thing particularly curious or useful; without entering into a detail of the chemical writers, which indeed would be endless.

CLASS I. Systematical Writers.

ZACH. Brendelii, *chymia in artis formam redacta, ubi præter methodum addiscendi enchiridese chymicas, facillimam, disquisitis curata de famosissima præparatione auri potabilis, instituitur.* Jen. 1630. 12mo.—Ed. 11. cum *Præf. Wern. Rolschii.* Jen. 1641. 8vo.

P. Thibaut, cours nouveau de la chymie. 12mo.

— in English, under the title of the art of chemistry, as now practised, Lond. 1668. 8vo.

A compleat course of chemistry, containing not only the best chymical medicines, but also great variety of useful observations. By George Wilson. The fourth edition. Lond. 1721. 8vo. This book contains the chief part of the chemical preparations now in use, with the processes faithfully described.

Car. de Maets, prodromus chemia rationalis, præcedunt animadversiones in librum cui titulus collectanea chymica Leidensia. Lugd. Bat. 1684. 8vo.

— *Praxis chymiatrica rationalis.* Lug. Bat. 1687. 4to.

— *Chimia rationalis, auctore T. P.* Lug. Bat. 1687. 4to.

Mich. Ettmulleri chimia rationalis ac experimentalis curiosa, secundum principia recentiorum adornata, variisque ac propriis experimentis, tam chymicis quam practicis, ut & medicamentis nobilioribus referta, comite semper ratione; in ordinem redacta & edita, per Job. Chr. Ansfeld. Lugd. Bat. 1684. 4to.

Staphorst officina chymica Londinensis. 1685. 8vo.

Chr. Leve Morley, collectanea chymica Lei-

densia, seu medicamenta Maëtiana, Morggraviana, & le Mortiana, &c. Lug. Bat. 1684. 4to.

— Revised by Theod. Mayhew. Lugd. Bat. 1693. 8vo. and Ant. 1702. 8vo. — In *Hisp. Dutch.* Jen. 1695. 8vo. — This book contains above 600 medicinal processes.

Antoine Deidier, chimie raisonnée, où l'on tâche de découvrir la nature & la manière d'agir des remèdes les plus en usage en médecine & en chirurgie. Lyon. 1715. 12mo.

Ern. Gesh. Struve, paradoxum chymicum sine igne, i. e. Operationes & experimenta physico-chymico-pharmaceutica, ipsaque medicamenta chymica, ignis opæ parari solita, sine igne exhibet. Jen. 1717. 8vo.

M. Senac doct. en médecine, nouveau cours de chymie, suivant les principes de Newton & de Stahl. Paris 1723. 2 vol. 12mo. and *ibid.* 1737.

Herman. Frid. Teichmeyer institutiones chemiæ dogmaticæ & experimentalis, in quibus chemicorum principia, instrumenta, operationes & producta; simulque analyses trium regnorum succinctâ methodo traduntur. &c. Jen. 1728.

Jo. Frid. Cartheuseri elementa chemiæ medicæ dogmatico-experimentalis, una cum synopsi materiæ medicæ selectioris. Hal. Magd. 1736. 8vo.

Joan. Juacheri, conspectus chemiæ theoreticæ-practicæ. Hal. Magd. 1730. 4to.

Job. Helfrici Jungken corpus pharmaceutico-chymico-medicum universale, seu concordantia pharmaceuticorum compositorum discordant, modernis medicinis practicis dicata. Ed. 3. prioribus longe auctior edita, per Davidem de Spina. Franc. 1732. fol.

CLASS H. Writers in Metallurgy.

And. Libavius, of Hall in Saxony, who died in 1616, has wrote largely of the nature, and examination of mineral; so as to be even set on a level with Agricola, for the history of

metals he publish'd. See his works; particularly the following,

Commentaria metallica.
Ars probandi mineralia.

J. Web-

J. Webster's *history of metals*, i. e. of the signs of minerals, of their vegetability, of the philosopher's gold, mercury, alkabest, &c. Lond. 1671. 8vo.

Alonso Barba. *trattato de l'arte metallico compuesto en Espagnol. en Cordoua 1674. V. Journ. des Savans. T. 4. p. 33. seq.* His long residence at Potosi in Peru had enabled him to make many observations relating to the mines. See the same in *English* by the earl of Sandwich. Lond. 1674. 8vo. See also *Phil. Transact.* No. 108. p. 187.

Libro segundo de l'arte metallica, en Cordoua,

The same in *English*, by the earl of Sandwich. Lond. 1674. 8vo.

It was reprinted at Lond. 1738, in 12mo, with the addition of a third part; containing a discovery of all sorts of mines, from gold to coal, by Mr. G. Platts; and a 4th part, entitled *Houghton's compleat miner*.

Il Marchese, Marco Antonio della tratta, della prattica minerale. in Bolog. 1676. 4to. Vid. *Hook Phil. Collect.* No 3. p. 80.

M. Reaumur's treatise of converting forged iron into steel; and to soften cast iron, so as to make utensils thereof equally perfect with those of forged iron. Paris an. 1722.

Em. Swedenborg, member of the metallic college in Sweden, *prodromus principiorum rerum naturalium, sive novorum tentaminum chymiam & physicam experimentalem explicandi*. Amst. 1721. 8vo.

CLASS III.

Jo. Fred. Helvetii, vitulus aureus quem mundus adorat & orat. Treating of the rare miracle of nature, the transmutation of metals, and shewing how the whole substance of lead was at the Hague in a moment's time converted into pure gold, by a small particle of the philosopher's stone. Amst. 1667. 8vo. and Hag. Com. 1702. 8vo. Printed also in Manger's *Bibl. Chym.* T. 1. p. 196. In *English*, under the title of *Helvetius's golden calf*. Lond. 1670. 8vo.

De alchymia, opuscula complura vet. philosoph. cum fig. Francof. 1550.

Four treatises of the philosopher's stone, by Alphonso king of Portugal, John Sawtre, and Florianus Randorf, a German. Lond. 1652. 4to.

Jo. Seg. Weidenfeld, four books concerning the secrets of the adepts; or the use of Lully's

Principia rerum naturalium, sive novorum tentaminum phanomena mundi elementaris philosophice explicandi, cum figuris aeneis, 3 vol. folio. Dresd. and Lips. 1734. This book opens a new scene in natural philosophy; and is large upon the business of metals.

There is a curious metallurgical book just published in *Higb-Dutch*, by Christ. Andreas Schluter, containing the whole art, both of smelting and assaying, as taken from the works themselves; and exhibited to the eye by numerous beautiful copper plates. folio. The title of it is *Gruntlicher Unterricht, &c.* or, 1. A fundamental description of mineral works; shewing the genuine way of explaining them with the several mechanical structures and furnaces thereto relating; with the manner wherein they are practised at Harz, and other mineral works: particularly the various methods of treating gold, silver, copper, and lead-ores; sulphur, vitriol, &c. 2. The whole art of assaying; containing the ways of trying all sorts of metallic ores, refining of silver, separating it from gold to advantage, &c. 3. A set of copper-plates for the two parts, executed according to a scale; with a proper index to each part. By Christopher Andrew Schluter, super-intendant at Under-Harz to his Majesty of Great-Britain, &c. Brunswick, printed by Frederick William Meyer. 1738.

Writers in Alchemy.

spirit of wine. A practical work collected out of the fathers of adept philosophy reconciled together. Lond. 1685. 4to.

Jac. Tollii, fortuita, in quibus præter critica nonnulla, tota fabularis historia Græca, Phœnicia, Egyptiaca, ad chymiam pertinere asseritur. Amst. 1687. 8vo.

Manuductio ad cælum ebemicum. Amst. 1688. 8vo.

Sapientia insaniens, sive promissa chemica. Amst. 1689. 8vo.

Gabr. Clauderi, scheidiasma de tinctura universalis, vulgo lapide philosophorum, cum Petr. Jo. Fabri MS. res alchymorum obscuras, explanante, necnon Ad. Gottl. Berliccii dissertationes de medicina universalis, quin & Eman. Koenigii epistola de elixirio sopherum. Norib. 1736. 4to

CLASS

CLASS IV. Writers in Philosophical Chemistry.

Jac. Barneri chymia philosophica perfecte delineata, docte enucleata, & feliciter demonstrata, &c. Noriberg. 1689. 8vo.

Jo. Freind, prælectiones chymicæ, in quibus omnes fere operationes ad vera principia, & ipsius naturæ leges radiguntur, Amst. 1710. 8vo. and Lugd. Bat. 1734. 8vo.

— The same in *English*, by *J. M.* with the author's defence of the work against the editors of the *Ad. Erud. Lips. Lond. 1713. 8vo.*

Claude Bourdelin, author of several chemical papers in the *Mem. de l'Academ. R. des Sciences.*

John Brown wrote an account of the quantity of rosin in the cortex eleuther. extant in the *Phil. Transact. No. 371. p. 81.*

— Observations and experiments on the *sal catharticum amarum*, or *Epsom salt. ibid. No. 377. p. 348 and 371.*

— Experiments on the *Prussian blue. ibid. No. 381. p. 15.*

— On camphire. *ibid. No. 390. p. 361.*

— *Davissoni philosophia pyrotechnica, cum fig. Par. 1641. 8vo.*

Du Clos, observations sur les eaux minerales de plusieurs provinces de France, fait in l'Academie R. des Sciences. à Paris 1675. 12mo. *V. Phil. Transf. No. 125. p. 612.*

— *Dissert. sur les principes des mixtes naturels. Amst. 1680. 12mo. V. Jour. des Savans. T. VIII. p. 290.*

Car. Newman, chemist to the king of Prussia, on fix'd alkaline salts, 1st part, *ap. Phil. Transf. No. 392. p. 3. 11d part, ibid. No. 393. p. 45.*

— On Camphire, *ib. No. 389. p. 321.*

— On the method of proving *Ererb brandy. ib. No. 391. p. 398.*

Car. Masitani, pyrotechnia soppica, &c. Neap. 1683. Colon. Alabr. 1701. 4to.

— *Opera omnia. Genv. 1716. folio.*

Jo. Vigan medulla chymicæ. Lond. 1682. 8vo. Gadan. 1682. 8vo. Jen. 1687. 8vo.

And. Cassii, de extremo illo & perfectissimo natura opificin ac principe terrenorum fide, auro; de admiranda ejus naturâ, generationis, effectibus, atque ad operationes artis habitudine. Hamb. 1685. 8vo.

Boulduc, method of discovering the sophistication of corrosive sublimate. *Mem. de l'Acad. R. des Sciences. 1699. p. 64.*

— Examination of the mineral waters of *St. Amand. ib. p. 68.*

— Analyses of a great number of plants, &c. as *Ipecacuanha. 1700. p. 1. and 97. Colocynthis. 1701. p. 15. Jalap. 1701. p. 39. Gum gutta. 1701. p. 172. Scammony. 1702. p. 248. Gratiola 1705. p. 245. Cachou. 1709. p. 293. Rhubarb. 1710. p. 217. Mechoacan. 1711. p. 104. Bryony. 1712. p. 53.*

— On the lixiviums of the waters of salt-petre. 1720. p. 589.

— On the properties of a new salt discovered in Spain. 1724. p. 168.

— Besides other analyses only mention'd in the history of the royal academy of sciences.

J. Juncker, conspectus chemiæ theoretico-practicæ in forma tabularum representatus: in quibus physica, præsertim subterranea & corporum naturalium principia, habitus inter se, proprietates, vires, & usus, itemque præcipue chemiæ pharmaceuticæ & mechanicæ fundamenta; à dogmatibus Becheri & Stahliani potissimum explicantur. P. 1. Hale Magd. 1739. 4to. The second part not yet published.

CLASS V. Bibliotecarii chemici.

Wilb. Grataroli, veræ alchemiæ scriptores. Bas. 1561. folio.

Petri Borelli, bibliotheca chymica, seu catalogus librorum philosophicorum, hermeticorum, in quo quatuor millia circiter autorum chymicorum, vel de transmutatione metallorum, re minerali & arcanis, tam manuscriptorum quam in lucem editorum, cum eorum editionibus usque

ad annum 1653 continentur. Par. 1654. 12mo. Heidelb. 1656. 12mo.—The authors are here enumerated in alphabetical order, but not with due distinctness nor fullness. V. Fabric. Bibl. Græc. I. 6, 7. p. 746.

Nath. Albini, bibliotheca chemica contracta, in qua continentur, 1. J. Aur. Augurelli chrysopæia utraque. 2. Gsmusolita novum lumen chemicum.

The History of CHEMISTRY.

chemicum. 3. *Anonymi Galli enchiridion*. Genov. 1653 and 1673. 8vo.

Bibliotheca chemica contrahita, continens tractatus quatuor. Genov. 1653 and 1654. 8vo.

Aureum vallas, oder goldene scheide, &c. The golden fleece, wherein are contain'd all the writings of the most celebrated authors in alchemy, &c. High-Dutch. Hamb. 1708. 4to. Tom. II. Bas. 1604.

Will. Cooper, catalogue of chymical books, which have been written originally, or translated into *Englsh*, in three parts. Lond. 1672 and 1675. 8vo. The third part, containing an index of such things published in the

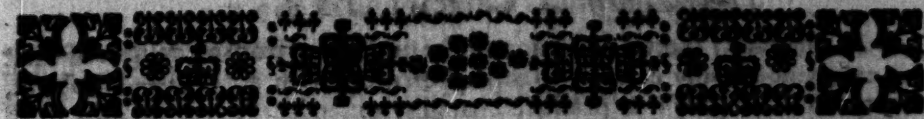
philosophical transactions of the royal society, as pertain to chemistry, or the study of art in the animal, vegetable, or mineral kingdom.

Jo. Jack. Mangesi, bibliotheca chymica, sive collectio scriptorum, præstantissimorum chemicorum, &c. Francos. 1702. 2 vol. folio.

Frid. Rothscholtzii bibliotheca chemica, oder catalogus von chymischen-buchern, &c. Ist, IId, IIIId, and IVth parts printed separately. Nurb. and Altorf. 1725—1728. It is alphabetical; we have only seen so much of it as extends to the middle of H: whether any more have been since printed, we doubt.



PART



P A R T II.

CONTAINING THE

T H E O R Y

O F

C H E M I S T R Y.

“ 1. **C**HEMISTRY is an art which teaches the manner of performing *Chemistry de-*
 “ certain physical Operations, whereby bodies cognizable to the senses, or *fin’d.*
 “ capable of being render’d cognizable, and of being contain’d in ves-
 “ sels, are so changed, by means of proper instruments, as to produce certain deter-
 “ mined effects; and at the same time discover the causes thereof; for the service
 “ of various arts (a).”

(a) The definition presupposes a competent number of chemical experiments already made and describ’d; which being reduc’d to rule, deliver’d with their circumstances, and digested in proper order, make the first elements of chemistry; and this is the thing particularly labour’d in the practical part; and was never, that we know of, so successfully attempted before: and herein we take the principal merit of the author to consist; he having not so much added any new matter, as collected the theory, or preliminaries of the art, and reduced the more common and ordinary experiments to *method*; thus giving the common chemistry, as already known and practis’d, the body and form of an art. Tho’ this is to be understood of the rudiments chiefly; for he has but lightly touch’d upon the medical, philosophical, mechanical, metallurgical, commercial, and alchemical parts; which might also be reduced to me-

2. As
 thod, and afford new elements of chemistry. Whence it is proper to observe, that arts can never be justly defin’d, till their nature, extent, and uses are fully known, and particularly ascertain’d; a true scientific definition being nothing more than a general truth, or expression, summing up, or including all the particulars from whence it was deriv’d. But the desire of making chemistry an art, may have prejudicial effects; if we thence confine it within too narrow bounds: which is generally the case when definitions are form’d, before the matter to be defin’d is brought to maturity.

The author, to shew that his definition of chemistry is just and adequate, takes it to pieces, and explains every part thereof; and such explanation comprehends the *theory* of chemistry; or the chemical doctrine of bodies.

Now chemists usually divide all sensible nature into three classes, called kingdoms, *viz.*

K the

Chemistry an
art.

Object of che-
mistry.

Divided into
kingdoms.

Fossils defin'd.

2. As chemistry directs operations to be performed from a foresight of what will ensue, it is truly entitled to the appellation of an art (*b*).—Its object, whereon it is employ'd to produce changes, extends, we see, not only to all sensible bodies, but even to insensible ones, provided they are capable, by any art, of being render'd sensible, either in themselves or in their effects; especially such as may be collected and contained in vessels, either naturally, or by any means we can employ for that end (*c*): which bodies on a careful review have been found commodiously reducible to three capital classes, by the chemists called kingdoms.

3. The first class contains *Fossils*, or as they are more usually called, *Minerals*; which are defined “natural bodies, found either in the bowels or on the surface of the earth; of so simple a structure that the closest inspection, even by the best microscopes, has not been able to discover any diversity between the vessels and their contents; but each part appears perfectly similar to the whole; tho' in many of them there certainly is a composition of solid and fluid parts (*d*).”

Of

the *fossil*, *vegetable*, and *animal* kingdom. This division, which at first sight appears gross and inaccurate, is, in reality, subtle and adequate; being taken from the three different manners of growth which obtain among bodies. For, excepting the four primary elements, fire, air, water, and earth, 1. All bodies either grow adhering to the earth, in such manner, as that there is no apparent distinction of parts containing and contained, (*viz.* of vessels and juices circulating in them) which are called *fossils*: Or, 2. They grow adhering to the earth, so that there is a real difference of vessels and juices discernible therein; which are *vegetables*: Or, 3. They grow without adhering to the earth at all; and are called *animals*. Each of these are consider'd in order.

(*b*) Being thus distinguish'd from casual experiments, or random trials, which, however, laid the foundation of the art, produced considerable effects, and made many unexpected discoveries: Thus gun-powder, phosphorus, *agua fortis*, and most of the chemical secrets, were at first accidental discoveries.

(*c*) Our author's economy here is admirable: his definition is an epitome of his book; or the book a paraphrase on the definition. He first gives us the whole in miniature; then takes every part in its order, and enlarges it. When he comes to *body*, that complex thing, the reader would imagine he had lost the view; but, after dilating and opening it by degrees, 'till he has discovered all it contains, he returns and goes thro' the rest. This hint will let the reader into a method, beautiful beyond expression.

(*d*) This character holds of fossils, and of them alone: thus gold, silver, and the other metals, antimony, salts, sulphurs, stones, and other minerals, really grow *fixed to the earth*; and if they be divided into the minutest parts, they will every where appear the same similar solid matter, without any *show of vessels and juices*. And thus, should it be urged, that spirit of wine must, on this footing, be a fossil, because homogeneous in all its parts, and exhibiting no distinction of vessels and juices; the answer is obvious: since spirit of wine, as such, is not *generated of, or under the earth*; neither is it a *vegetable*; that denomination including the whole compages or structure, out of which the spirit of wine is prepared. Or if it be said, that *antimony* should then be no fossil, since it contains an heterogeneous sulphur: it may be answer'd, that as to our senses, 'tis in all respects a fossil; since whatever portion you take thereof, 'tis the same indistinguishable matter, and has all the characters of antimony.

Fossils are either simple, or compound: *simple*, are such whose parts, howsoever divided, are all of the same nature, that is, of the same gravity, magnitude, figure, hardness, and mobility: as quick-silver, which, tho' divided to infinity, is found every where the same in all these respects. *Compound* fossils are those which may be resolved into different, or dissimilar parts; or, whose parts are unlike in magnitude, figure, hardness, and mobility: as antimony, which may be resolved by fire into a sulphur, and a metallic part.

The

Of METALS.

1. The first bodies in the fossil class are *Metals*; whose characteristics are to be "the heaviest of fossils, fusible by fire, but cohering again in the cold, so as to become ductile and distensible under the hammer."

2. Of these in all ages have hitherto been found only six simple ones, viz. *How many metals.* gold, silver, copper, tin, iron and lead. The ancients indeed added quicksilver to the number; but this, as wanting hardness, ductility and fixity, has no pretensions to be a metal (*e*). However, the great affinity it bears to the rest, in respect of weight, simplicity, the place where it is found, and its easy uniting with other metals, has given rise to a very ancient opinion, which prevails much at this day, that mercury is the chief basis or matter of all the metals. *Mercury, if a metal.*

3. It appears somewhat surprizing, that the ancient *Persians* in their religious rites, always called the seven metals, which they knew were produced in the earth, by the names of the seven planets found in the heavens. And what is more, the astronomers and astrologers still make use of the same characters, viz. ☉, ♀, ☿, ♄, ♃, ♀, ♁, to denote the planets, as the chemists do to represent the metals. Whence a doubt may arise, among which of the two these characters were first used? Those of the chemists 'tis certain are well adapted to express their respective bodies, according to the hieroglyphic method; as will appear from a closer examination. *Ancient characters of metals. Used also for the planets. Significations of the characters.*

K 2

4.

The simple fossils are, (1) *Metals.* (2) *Salts.* (3) *Stones*, both vulgar and precious; and, (4) *Earths.*

The compound fossils are, (1) *All sulphurs.* (2) *Semi metals*, or properly, *minerals*; and, (3) Bodies combined of the preceding fossils, either simple or compound.

Metals making the primary class of fossils, the author treats of them in the first place.

(*e*) Viz. According to the definition here laid down, which, however, may perhaps be only arbitrary. See the account of quick-silver below.

Such is the proper idea of a *metal*, which is no way applicable to any other body in nature: for a diamond, tho' a simple body, is not fusible in the fire, nor capable of being stretched under the hammer. And salt, tho' dissolvable by fire, is not malleable, but breaks under the hammer. It may be added, that there are certain woods, which yield in some measure to the hammer; but then they fall to ashes in the fire; and so of the rest.

The author has said nothing here of the origin, or formation of metals, which there are several hypotheses to account for. Some suppose the metallic particles were form'd at the creation of all things, and rang'd by the law of gravity in regular strata, near the centre of the earth; from whence they have

since been rais'd, by the action of the central heat, up towards the surface, and deposited there in various parts of the globe. Others set aside this pre-existence, and suppose metals to be form'd, or generated *de novo*, by the accidental mixture of certain particles, not metallic till they mixed. And some will have it that metals have their origin from seeds, or eggs; whilst their production is only the opening, or expansion of these seminal parts, in the nature of organized bodies, with vessels and juices circulating in them. But whoever carefully attends to all the phenomena of mines, and compares the appearances of all sorts of ores, as we find them in the cabinets of naturalists, will perhaps see sufficient reason to think, that all metals were once in the form of vapour or fume, which gradually lights and settles upon particular stony mineral substances, preferably to the rest, as if they affected certain bodies, from a secret relation between them, and thus receive increase and growth from the constant accession of similar fumes, till at length they appear in the form of ores, visible metallic grains, or differently figur'd lumps of their own kinds respectively; somewhat after the manner of crystallization. This, at least, is the best account that we can at present give of the matter.

- Corrosive.* 4. + denotes any thing sharp, gnawing or corrosive; as vinegar or fire: being supposed to be stuck around with barbed spikes.
- Gold.* ©. Denotes a perfect, immutable, simple body, such as gold, which has nothing acrimonious, or heterogeneous adhering to it.
- Silver.* D. Denotes half gold; whose inside if turned outwards would make it entire gold: as having nothing foreign or corrosive in it; which the alchemists observe of silver.
- Quick-silver.* S. Denotes the inside to be pure gold, but the outer part of the colour of silver, and a corrosive underneath; which if taken away would leave it mere gold. And this the adepts assert of mercury.
- Copper.* P. Denotes the chief part to be gold; whereto however adheres another large, crude, corrosive part; which if removed would leave the rest possessed with all the properties of gold. And this the adepts assert of copper.
- Iron.* δ. Likewise denotes gold at the bottom, but attended with a great proportion of a sharp corrosive, sometimes amounting to half of the whole; whence half the character expresses acrimony, which accordingly both alchemists and physicians observe of iron. And hence that common opinion of the adepts; that the *aurum vivum*, or gold of the philosophers, is contained in iron; and that the universal medicine is rather to be sought in this metal than in gold itself.
- Tin.* ʒ. Denotes half the matter of tin to be silver, the other a crude corrosive acid: which is accordingly confirmed by the assayers; tin proving almost as fix'd as silver in the cupel, and discovering a large quantity of crude sulphur well known to the alchemists.
- Lead.* h. Denotes almost the whole to be corrosive, but retaining some resemblance with silver; which the artists very well know holds true of lead.
- Antimony.* δ. Denotes a chaos, *τὸ πᾶν*, world, or one thing which includes all: this is the character of antimony; wherein is found gold, with plenty of an arsenical corrosive (f).

(f) 1. The elements of chemistry, perhaps, should rather be kept clear of these cabalistical conceits, for fear of giving a wrong turn to the mind at its first setting out in this practical science; tho' they may have their use in reading the alchemistical authors.

2. These characters appear to have been in use amongst the most ancient chemists. They are said to be of a thousand years standing; and to have been originally taken from the religion of the *Persians*. 'Tis certain, there have always been two ways of writing; the one by *letters*, arbitrarily pitch'd on to denote things; as that in use among us: the other by *characters*, or images of the things denoted, call'd *hieroglyphics*; such was that of the ancient *Egyptians*; who to denote a dog, put a dog's head; for a stout man, a lion; for a perfect thing, a circle, &c. which manner still obtains among the *Chinese*; and hence that difficulty, so much complain'd of, in learning their language; the number of

5. The their characters being so great, that even the most learn'd of their *Mandarins* scarce understand a twentieth part of them. The images they use are such as we sometimes see in our porcellane, or china-ware, which those people can read. This hieroglyphic, or cabalistic manner of writing was adopted by the chemists; who denoted their metals by characters, that seem drawn from the very depths of chemistry, and hold forth the intimate nature of the metals themselves. Their first character © gold is a circle with a point in its centre: now the circle is a symbol of perfection, and simplicity; and was always used as such by the ancient caballists: in reality, there is no figure more simple, uniform, or perfect than this; it comprehends the greatest space, under the least superficies; and all the *radii* drawn from its centre to its circumference are equal: properties which correspond very aptly to the sun in the heavens, and to gold on the earth. For gold is the

most

5. The proper and specific characteristic of metals consists in their weight, wherein they far surpass all other bodies. And this property being the most difficult

Specific gravity characteristic of metals.

most simple of all metals, and at the same time it is the most perfect; as being by the heaviest, and including the greatest quantity of matter under the least surface. Its nature, therefore, is well denoted by the figure.

3. ☾ is the character signifying silver on earth, and the moon in the heavens. This figure would be a perfect circle, if the inner part were properly applied to the outer. Now the chemists all agree, that silver is half gold; or part of it gold, only that part lies hid. Accordingly its character denotes gold half perfected; for, say they, if you can but turn the gold part that lies hid in the silver outwards, your silver will be converted into gold. Thus gold being accounted the most perfect of all metals, silver comes the nearest thereto; consequently, 'tis a sort of semi-gold. Mons. *Homburg* shews, that pure silver, perfectly purg'd of all gold, being kept along time in the fire, always gains a little portion of gold, that is, part of it becomes gold.

4. ♀ Copper, is a circle, with a cross underneath; and denotes, that the body or basis is gold, tho' join'd with some corrosive menstruum. For a cross is the character whereby all corrosives, as fire, vinegar, and other sharp dissolvents, were denoted by the ancients; those being things that used to torment, and as it were crucify: now, all the adepts allow copper a nobler metal only debased by a sharp corrosive, or arsenical poison, adhering thereto, which is capable of destroying men, and which, when taken away, the copper is left gold. Accordingly, copper of all metals, silver only excepted, is allow'd to come the nearest to gold.

5. ♂ Iron, this character likewise denotes gold at the bottom, only its upper part is too sharp, volatile, and half corrosive; which being taken away, the iron would become gold. Accordingly, the chemists hold that iron comes nearest to gold after copper. 'Tis *Basil Valentine's* tenet, that *Mars* and *Venus* together make *Sol*. The same author introduces iron by way of prosopopœia, saying, if you put off my clothes, that is, the corrosive, you will come at my soul, that is, the intrinsic nature of iron.

6. ♀ Tin is held to be one half luna, or silver, and the other half corrosive; which is denoted by the femicircle, and the cross added thereto. In effect, it comes the nearest of all metals to silver, and has most of the properties thereof, excepting weight: and they agree in this particular circumstance,

that they both grow bitter in acids; which no other metals do. Mr. *Boyle* suspects, that tin and silver may be the same body; only that there is much corrosive sulphur in the former: hence silver and tin fused together, mix and cohere so intimately, that they can scarce be separated, even by lead.

7. ♀ Lead, appears to be the character of tin inverted, with the corrosive passing thro' the middle. It is variously wrote, has fre-

quently a double cross $\frac{+}{\times}$, to shew that it corrodes on all sides. Accordingly, all metals are destroy'd by lead; gold and silver only excepted: and hence this character is used to denote it principally as a corrosive, tho' the middle part bears some resemblance to silver; as there is a real correspondence between lead and silver.

8. ☿ Quicksilver evidently shews gold in the middle, or body of it, silver at top, or in the face, and a corrosive at bottom: accordingly, all the adepts say of mercury, that it is gold at heart, whence its heaviness; that its outside is silver, whence its white colour; but that there is a pernicious, corrosive sulphur adhering to it, denoted by the cross; that the quantity of sulphur is here so great, as to render it wholly volatile in the fire; that the more 'tis burnt, the nearer it comes to gold; and that were it perfectly calcined and purified, and its colour changed, it would be gold.

9. ♂ Antimony is a circle denoting the body of gold; to which a cross is added, to shew it a corrosive; and because the corrosive prevails, the cross is placed at top. Accordingly, antimony is the destruction of all metals, except gold; the other five, with stones, salts, &c. being all lost in the corrosive. Again, the character of antimony is the same with that of *tellus*, or the earth; as being a sort of chaos, or universal body; and accordingly *Basil Valentine* calls it all in all.

10. We now see why the ancient chemists had recourse to a kind of images of bodies, and directed their followers to seek for all things in the grand world; as we see in *Pantaleon* and *Suchten*. The truth is, something obtains in the planets and heavenly bodies, like what we see in minerals; so that there is a foundation for the allusion.

11. Whoever has a desire to see more of these ancient chemical symbols, may find a large table of them in *du Cange*, though incorrectly printed. Vid. *Gloss. Græc.* T. 11. p. 17, 22.

The Theory of CHEMISTRY.

ficult to be procured by art, affords us a certain criterion, whereby metals may be distinguished. The weights of the several metals in proportion to that of pure water may be assigned, from the *Philosophical Transactions* (g), thus,

Gold	19636
Quicksilver . . .	14019
Lead	11345
Silver	10535—11087
Copper	8843
Iron	7852
Tin	7321
Granate	3978
Glass	2805
Pump-Water . . .	1000

*Its use in
judging of
metals.*

6. Hence arises the best method of examining unknown bodies, in order to learn whether they contain any considerable quantity of metal. And by the same means we also frequently learn of what kind the latent metal is. Hence also appears the great difficulty of increasing weight, so as by condensation to turn other metals into gold, or other bodies into metals. And again we learn from hence what matter comes the nearest to gold, and is the readiest for being changed into it, with regard to weight (b).

Of G O L D.

*Gold, its cha-
racters.
Weight.
Simplicity.*

1. Gold is (i) the heaviest and densest of all bodies (i).
- (2) The most simple (k) of all bodies (l).

(g) *Phil. Trans.* N°. 169. p. 926. and N°. 199 p. 694.

(b) This criterion of metals perhaps is not so absolutely certain as to be depended upon in all cases; some marcasites that yield no metal, are as heavy or heavier than true ores; and some tin-ore, as particularly that call'd tin-grains, is specifically heavier than the metal it affords; and I am assur'd by an unexceptionable judge, that he once examin'd a mineral substance, specifically heavier than gold: so precarious a thing it is to form general rules, before all the instances are sought out on both sides of a question. And this should be carefully remember'd, as we proceed in the history of metals, otherwise we may reason wrong in a very material point, and imagine ourselves fully possess'd of truth, whilst we are really under a mistake.

(i) We observe that it weighs above nineteen times more than water, taking bulk for bulk: and this property is inseparable from it; no certain method having yet been found out to render gold more or less heavy: so that tho' all the other properties of gold

(3) The may perhaps be imitated, its weight alone seems inimitable. Wherever, therefore, we find the specific gravity of gold, there is probably real gold; so if I have a mass of matter heavier than mercury, there may be a share of gold in it, since, as already observ'd, we find no intermediate body between mercury and gold; for instance, no body which is to gold as 16, or 18 to 19. Whoever, therefore, would make gold, must be able to add to the weight of other metals; so as to render them equiponderant with gold. Hence, if any fraudulent alchemist should obtrude a metal on you for gold, take a piece of pure gold, hang it by a hair or thread to a nice balance, and hang an equal weight of the suspected gold by another hair, to the other end of the beam; then immersing both pieces in water, if the alchemist's gold be pure, the water will retain both pieces in *equilibrio*, otherwise, the adulterate metal will rise, and the pure descend.

(k) Unless the purest mercury be an exception.

(l) By a simple body we mean that whose minutest part has all the physical properties

of

(3) The most fixed of all bodies; both in air and fire; insomuch that an ounce of it being exposed for the space of two months in the eye of a glass-furnace, it lost not a single grain: whence it appears to be incorruptible.

(4) The only body that resists the force of antimony and lead (m); neither of which will turn it into *Scoria*; but being melted with them, it sinks to the bottom. Hence it is the least changeable of all bodies hitherto known, and even perhaps utterly immutable by any physical causes. Whence the alchemists unanimously assert that it is easier to make gold then to destroy it (n).

of the whole mass. Thus, if a grain of gold be dissolv'd in *aqua regia*, and a single drop of the solution be taken; a particle of gold may be separated therefrom, which shall only be the millionth part of the grain, and yet have all the characters of gold, except those that depend upon magnitude. Or, if you fuse a single grain of gold with a mass of silver, and mix the whole together; so that the gold shall be equally distributed thro' the whole mass; you will have in a particle thereof a particle of perfect gold, in all respects like the whole grain. Accordingly, dissolve any part of the mixture in *aqua fortis*, and a quantity of gold will precipitate to the bottom; bearing the same proportion to the grain, that the part dissolved did to the whole mass.

And on this principle chiefly depends the art of assaying; for if you carry a mass of gilt silver to an artist, he takes a single grain thereof, melts it to mix the gold and silver well together, then puts it into *aqua fortis* to dissolve the silver, upon which the gold falls to the bottom. And from the proportion of the gold so found, to the whole grain, he computes how much gold is in the whole mass.

The alchemists, however, hold their *aurum philosophorum* to be still more simple than gold; as consisting of mercury perfectly clear'd from all sulphur; but whether there be any such thing in nature, will admit of a question; mercury, absolutely pure, and free of sulphur, being what we must acknowledge ourselves never to have seen.

(m) By *resisting*, we mean, that when melted with them in a cupel, it does not dissipate, and fly off in fume, but remains fix'd. The chemists have two kinds of lead, or *Saturn*; viz. the *Saturn* of *Luna*, or common lead; and that of *Sol*, called also the *Saturn* of the philosophers, which is antimony. No bodies but gold and silver resist the first; and none but gold alone resists the second; they term each of them *lavacrum leprosum*, or the *leper's bath*; intimating hereby, that all other metals, except gold and silver, being tested with lead or antimony, fly off in fume. Lead, particularly, they call *balneum solis & luna*,

(5) The *the sun and moon's bath*; or *balneum regis & reginae*, the king and queen's bath; as silver and gold thence come out the purer, whilst all other metals are destroy'd therein.

Thus, if a mass consisting of gold, silver, copper, and other metals, together with stones, or other bodies, be fused with ten times their quantity of lead; the stones, and all other bodies not metallic, will flow on the surface, and be easily blown off by the bellows. In the mean time the lead drawing all the metals, except the gold and silver, to itself, rises along with them into a sort of dross; and is likewise blown off by the bellows, or goes away in fume, or vitrifies with the cupel.

As to antimony, a quantity thereof being put in a cupel, along with pure gold, and the whole fused, and kept in a strong fire, the antimony all evaporates, and leaves the gold alone: which does not hold of any other metal, not even silver itself. Whence antimony is particularly called *balneum solis*, the sun's bath, and *lavamen solius regis*; devorator, *lupus metallorum*, &c. Hence, antimony is used as the last test of gold; to try the purity whereof, a grain or two being tested with twenty times the quantity of *regulus* of antimony, till the antimony is either evaporated, or turn'd to a *scoria*, to be blown away by the bellows, and the gold have *fulminated*, as the refiners call it; that is, till its surface appears every where similar, and equable. This being done, if the gold have lost nothing of its weight, it is allowed perfectly pure, and called *gold of twenty-four carats*; or if it be found $\frac{1}{4}$ lighter, it is said to be twenty-three carats fine.

(n) Mr. Boyle gives us an experiment, wherein a quantity of pure gold was so chang'd and debas'd, by the admixture of an exceeding little quantity of a powder cast upon it in fusion; that, beside detaching a large metallinecrement, not unlike bell-metal, the gold itself was left of a dirty-colour, and lost its specific gravity so far, that instead of being nineteen times the weight of water, as at first, it was now only $15\frac{2}{3}$. This operation appear'd to Mr. Boyle almost as strange as projection. See Boyle. Abr. Vol. I. p. 78.

The Theory of CHEMISTRY.

(5) The most ductile of all bodies (o). The gold-beaters with their hammers, can extend a grain of gold between skins made of ox-gut, into a leaf containing 36 square inches and an half, and 24 square lines. So 48 ounces of silver formed into a cylinder, may be gilt with one ounce of gold and be afterwards drawn into fine wire, two yards whereof weigh only one grain, and consequently $\frac{1}{48}$ of a grain of gold is extended over the whole surface, which however, when viewed even with a microscope, is found so dense and close as not to discover the least atom of the silver under it. Consequently $\frac{1}{100000}$ part of a grain of gold is here visible to the naked eye; the thickness whereof exceeds not by computation $\frac{1}{111100}$ part of an inch (p). It has also been shewn that gold, on the finest silver-gilt wire is only $\frac{1}{100000}$ part of a line thick (q). A drop of a solution of gold in *aqua regia*, mixed with a pint of rectified spirit of wine, will communicate a metalline taste to the whole; added to a solution of two grains of tin in a very large quantity of water, it will give a dusky purple hue thereto. Lastly, *Hoffman*, a dextrous operator at *Ausburg*, by a very extraordinary process (r), drew a single grain of gold into a wire 500 foot long (s).

(o) Sir *Isaac Newton* suspects, that the primitive, or component particles of all bodies are hard; that they are only laid together; and that the cause of their cohesion is some attractive force superadded to them, whereby they unite together into larger particles, and those at length into sensible masses. Now, if the composition be so, as that the particles, under the circumstances of their attractive or cohesive force, are liable to slide easily on one another, the body becomes ductile, or malleable, or soft*.

(p) *Halley* in *Philos. Transact.* No. 194. p. 549.

(q) *Mem. de l'Acad. an.* 1713. p. 10.

(r) *Cassius de auro.* p. 77.

(s) Our gold-beaters and wire-drawers furnish us with abundant proofs of this property: they every day reduce gold into leaves, or *lamelle* inconceivably thin; yet without the least aperture or pore discoverable, even by the microscope: a single grain of gold may be stretch'd under the hammer into a leaf that will cover a house; and yet the leaf remain so compact, as not to transmit the rays of light, nor even admit spirit of wine to transude. Dr. *Halley* took the following method to compute the ductility of gold: he learnt from the wire drawers, that an ounce of gold is sufficient to gild, that is, to cover, or coat a silver cylinder of forty-eight ounces weight: which cylinder may be drawn out into a wire so very fine, that two yards thereof shall only weigh one grain; and consequently ninety-eight yards of the same wire only forty-nine grains. So that a single grain of gold here

(6) It gilds ninety-eight yards; and of course the ten thousandth part of a grain is here above one third of an inch long. And since the third part of an inch is yet capable of being divided into ten lesser parts, visible to the naked eye; it is evident that the hundred thousandth part of a grain of gold may be seen without the assistance of a microscope. Proceeding in his *calculus*, he found at length, that a cube of gold, whose side is the hundredth part of an inch, contains 2,433,000,000 visible parts: and yet, tho' the gold where-with such wire is coated, be stretch'd to such a degree, so intimately do its parts cohere, that there is not any appearance of the colour of the silver underneath.

Mr. *Boyle* examining some leaf-gold, found that a grain and a quarter's weight took up an area of fifty square inches: supposing, therefore, the leaf divided by parallel lines $\frac{1}{100}$ of an inch apart; a grain of gold will be divided into five hundred thousand minute squares, all discernible by a good eye. For gold-wire, the same author shews, that an ounce of gold drawn out therein, would reach 155 miles and a half†.

But M. *Reaumur* has carried the ductility of gold to a still greater length: a gold-wire, every body knows is only a silver one gilt. This cylinder of silver, cover'd with leaf gold, they draw through the hole of an iron; and the gilding still keeps pace with the wire, stretch it to what length they can. Now, M. *Reaumur* shews, that in the common way of drawing gold-wire, a cylinder of silver 22 inches long, and 15 lines in diameter, is stretch'd

* *Newt. Opt.* p. 370.

† See *Boyle Abr.* Vol. I. p. 405.

- (6) It is soft, and scarcely elastic or sonorous (*r*). *Not elastic.*
 (7) It melts by fire, but first ignites and grows red-hot (*u*); tho' in *Ma-* *Fusibility.*
dagascar there is a softer kind which fuses soon by a gentle fire, like lead (*x*).
 (8) It is dissolvable by sea-salt (*y*), and the preparations thereof; but remains *Dissolvent*
 untouch'd *with sea-salt.*

stretch'd to 1163520 feet; or is 634692 times longer than before; which amounts to about 97 leagues. To wind this thread on silk for use, they first flatten it; in doing which it stretches at least $\frac{1}{7}$ further; so that the 22 inches are now 111 leagues: but in the flattening, instead of $\frac{1}{7}$ they could stretch it $\frac{1}{4}$, which would bring it to 120 leagues. This appears a prodigious extension; and yet it is nothing.

The cylinder of silver might only have been cover'd with one ounce of gold, instead of six, which we have hitherto supposed: the gilding indeed in this latter case will be but thin; but still it will be gilding, and no point but will have its cover of gold. On this footing M. *Reaumur* computes, that the thickness of the gold-leaf on the wire, is $\frac{1}{1400000}$ of a line. He adds, that as the leaf-gold is not every where the same thickness, but at least twice as thick in some parts as others; in the thinnest parts it will not be above a 525000th part of a line, or the 6300000th part of an inch.

Yet this is not the furthest we can go: in flattening the wire gently between two wheels, it may be extended to double the breadth hitherto supposed; in which case the thickness of the leaf will be reduced to less than a millionth part of a line, or a twelve millionth of an inch.

Yet, after all, putting a piece of this gilt-wire in *aqua fortis*, the silver will be dissolv'd, and the gold left a perfect, continuous tube*.

This tenacity, or force of cohesion in the parts of gold, which appears scarce less than infinite, depends on its being freed from common sulphur: for mix but one single grain of sulphur with a thousand grains of gold, and the mass ceases to be malleable, till the sulphur be evaporated. And hence we have a strong presumption, that the less tenacious metals, tin, copper, and iron, contain a large quantity of sulphur.

The immense divisibility of gold is learnt from another experiment: for example, take a pound of silver, and fuse it with a single grain of gold; the gold will diffuse itself equally through every minute particle of the silver; so that taking a grain of the mass, and dissolving it in *aqua fortis*, you will find a quantity of gold fall to the bottom, which bears precisely the same proportion to the

grain of gold, as the gold in the mass had to the whole mass.

(*r*) Its sound, when pure, is not very clear, or tinkling, but rather obtuse, and resembling that of lead. For gold being soft and flexible, has but little elasticity, and consequently is not much disposed to the trembling, or vibratory motion necessary to produce sound. Add silver or copper to it, and it becomes sonorous enough: but without admixture, the alchemists even hold, that it yields no sound at all.

(*u*) It requires a pretty vehement fire to fuse it; greater considerably than either lead, or tin; tho' much less than iron, or copper. Some metals, as tin, for example, dissolve before they ignite; gold grows red-hot before it melts: the difference arises hence, that the one sustains a greater degree of heat than the other, in order to fusion.

(*x*) *Flacourt. Hist. Inf. Madagascar. ap. Borrich. de Ort. Chem. p. 49.*

(*y*) It is not dissolvable in any commonly known menstruum, except *aqua regia* and mercury. *Aqua regia* takes its denomination from this property of dissolving gold, which among the chemists is called *rex*, the king: its basis, or essential ingredient, is common, or sea-salt, which answers the purpose in whatever form applied; whether as a fluid, or a solid, a liquor or a spirit. Sal-gem, and sal-ammoniac, do either of them occasionally answer the same end as sea-salt; but 'tis only so far as they are of the same nature and kind with sea-salt; as will be shewn in the chapter of *salis*. *Aqua regia*, then, is a sort of *aqua fortis*, or acid spirit, wherein there is a small proportion of sea salt; 'tis prepared four several ways: (1) By mixing common salt, sal-gem, or sal-ammoniac, whether native or factitious, with *aqua fortis*, or spirit of nitre. (2) Of butter of antimony, from which Mr. *Boyle* made a menstruum that dissolv'd gold with surprizing readiness; but this does not infer, that gold may be dissolved without sea-salt; for butter of antimony is made partly of mercury-sublimate, wherein sea-salt is one ingredient. (3) Of sea-salt reduced into a spirit by distillation; for such spirit of salt is known to dissolve gold: and, (4) Of human urine; for this being distill'd by a vehement fire to make *phosphorus*, there remains at the bottom of the vessel, a sort of salt perfectly like

* *Mem. de l'Acad. an. 1713.*

Not liable to
rust.

Unites with
quicksilver.

Emits no ef-
fluvia.

untouch'd by any other species of salts. Hence it is not liable to rust; because *aqua regia* and spirit of sea-salt do not float in the air (x).

(9) It very readily unites itself with pure quicksilver (a): not so readily with crude as is usually supposed, even with heat. When dissolved in *aqua regia*, and precipitated with salt of tartar, it has a fulminating property (b).

(10) Nor ever wastes it self by emitting *effluvia*, or exhalations (c).

2. Gold

like sea-salt; which, mixed with spirit of nitre, makes a menstruum that dissolves gold.

To conclude, no spirit, or salt, whether acid, or alkaline, affects gold, unless it have a mixture of common, or sea-salt: thus, if you take a dram of gold, put it into a clean glass vessel, and pour upon it spirit of sulphur *per campanam*, oil of vitriol, or spirit of nitre, either hot or cold; they will have no effect on the gold; but it will remain untouch'd, as if it were a diamond: but if into so many vials, each containing one of these saline liquors, with a quantity of gold, you add a little sea-salt, or sal gem, either in form of a spirit, or of a lixivium, the gold will be dissolv'd; and soonest in the vessel that contains spirit of nitre.

(x) Unless in laboratories and chemists shops, where we find them often, and see odd effects produced thereby.

(a) It readily, and spontaneously, as if by some magnetic power, attracts, and absorbs mercury; but does not thus increase its specific gravity. We have made the experiment, and always found the gold dilated, or increased by the mercury in bulk more than in weight, and consequently its specific gravity diminish'd. Thus, if a grain of mercury be mixed with two grains of gold of twenty carats fine, and the mass be weigh'd hydrostatically against two grains of the same gold without mercury; it will be found specifically lighter: Add, that as soon as the mercury enters the gold, it is render'd soft, and like a paste; and of consequence is thinn'd, or diluted.

(b) Thus making what is called *aurum fulminans*, which gives a much smarter and louder report, than the common *pulvis fulminans*, and with a much less quantity.

(c) Gold is the most fix'd of all bodies; that is, it loses least in the fire. Natural bodies are reducible to two classes, *fixed* and *volatile*: the first are such as bear the utmost violence of the fire, without evaporating, or losing any thing of their weight: the second, such as fly away in fume, or *effluvia*. Now, of all metals, gold and silver alone are accounted *fixed*; but gold much more so than silver. *Gaſto Claveus*, the *Prince of Mirandula*, Mr.

Boyle, and others, have made experiments to this effect: a quantity of very pure gold being placed in the eye of a glass-furnace; it was found at the end of two months not to have lost any sensible part of its weight; tho' it had been all along kept in continual fusion; insomuch that other bodies would have thus been dissipated in a much less time.

Whence this property should arise, is not easy to say; unless the particles of gold being all homogeneous, and equal, equally sustain each other, and leave equal pores between them, through which, when fused, the fire finds an easy passage. The same property is observable, though not in the same degree, in silver: the other metals are much less fix'd, as containing too much sulphur, which volatilizes, and carries them off in fume. From this circumstance of fixity, some have argued, that gold alone has its just proportion of fire; and is itself no other than fire perfectly concentrated. But *M. Tschirnhaus*, and others, have made large double burning-glasses, in whose *foci* even gold itself readily volatilizes, leaving behind a part converted into glass. Some philosophers, however, contest the reality of this vitrification, 'tis certain that if gold be exposed to the focus of a burning-glass on a piece of charcoal, as is usually done, it sensibly diminishes; and in proportion to the diminution, there arise an infinite number of little glassy drops of a greenish colour, which swell, and enlarge in proportion as the gold disappears. But this, say some, "is no demonstration that the gold is vitrified: 'tis rather the ashes of the coal, which, uniting with the gold, afterwards vitrifies: "for let gold evaporate on a body which "yields no ashes, and you have no glass. Add, "that if this glass be fused over again, and a "fat matter added thereto, it does not return "to its former state of gold, as all other metals are found to do." The like experiments have been made at *London* with *M. Villette's* burning concave. Hence, we conclude that there is no body absolutely *fix'd* in all nature; since gold, which has the fairest pretensions, is not so.

It may be observ'd however, that gold mix'd with some volatile bodies, does evaporate;

2. Gold is sometimes found naturally pure in certain grains and lumps, *in what form found.* some of which have been of two pound weight. This is called *aurum obryzum*, which usually, however, requires a further purification by the fire; it being rare that any ore contains pure gold without a mixture of other metals; and especially of silver. Sometimes also there is lead mixed with it; but rarely any of the other imperfect metals. It is found in most parts of the world, in a greater or less quantity. Its ore is usually white, sometimes marked with black spots, which is the best kind: but there are also black, red, and yellow sorts in the mines. Among the ore are also found vitriols, both white, blue, red and green; and sometimes also antimony of gold, as it is called (*d*). *Pure obryzum.* *Ores of it.*

3. The

rate; but this is the effect of the great volatility of those bodies, which can carry off the gold along with them. "If we consider," says Mr. Boyle, how very minute the parts "are whereof gold consists, and into which "it is divisible, it will not seem impossible, "that if we could meet with volatile salts of "figures fit to stick fast to the corpuscles of "gold, they would carry these up along with "them. Accordingly, we have made more "than one menstruum, with which some par- "ticles of gold may be carried up: but upon "applying the *menstruum peracutum*, which "consists of spirit of nitre drawn from butter "of antimony, I was able, without a very "violent fire, and in the space of a few hours, "to raise so much crude gold, as afforded a "considerable quantity of sublimate*."

Gold exposed in a cupel to a large burning-glass, crackles, emits fumes, gradually diminishes, and leaves a ruddy dye around the vessel: 'tis, probably, no other than the earth of the metal that gives that redness; for there is no recovering of any thing like gold from it: so that one would imagine it something accruing from a sort of analysis of the gold.

These are all the sensible criterions of gold; whence it is next to impossible to be deceived therein: for wherever these ten properties occur, there is certainly gold; and where they are all wanting, there is none. Take, for instance, a single grain of metal, pretended to be gold, and which has many appearances of it, put it along with three grains of antimony in a cupel, and fuse it for the space of an hour: if the gold be pure, the whole grain will be found at the bottom; otherwise, the foreign, or adulterate part, will be all gone off, with the antimony: which is a proof there is no possibility of eluding, nor any danger of being deceived by. Such characteristics of metals, and chiefly of gold, are of frequent use in life; especially to persons who have to do with that subtle tribe, the alchemist.

The form wherein gold is found.

(*d*) Gold is found in three different manners or forms. 1. In pure glebes, or clods, consisting of gold alone; in which form it is sometimes said to be met with in Hungary: accordingly in the emperor's collection are preserved several lumps of pure gold, so found in the mines. 2. It is found in a powdery form, and then called gold-dust, or sand-gold, in the sands and mud of some rivers, brooks, &c. particularly in Guinea; being wash'd down from the mountains, or torn from hidden veins by the violence of waters, and gather'd up by the miserable natives. 3. It is also found, and that most usually, in whitish clods, dug out of mines and hundred and fifty or an hundred and sixty fathoms deep, intermixed with other fossils, as antimony, vitriol, sulphur, earths, stones, and other metals. 'Tis very rare that gold is found otherwise than under this last form: we have seen specimens from most parts of the habitable globe; but none of them pure, except those from the coasts of Guinea: tho' the greatest part brought from thence contains some impure heterogeneous parts; the Negroes being apt clandestinely to mix filings of brass or copper therewith. Lax. Ercker, assay-master to three emperors of Germany, under whose directions were all the mines of Germany, Hungary, Transylvania, and Bohemia, assures us, "that 'tis rare any earth produces pure gold; "but one metal or other still grows with it: "and even where it appears purest of all, it "has its share of silver." He adds, as an universal rule, "that where gold appears the "purest, there is silver mix'd along with it; "and where it is the hardest, there is both "copper and silver."

The mountains of Chili sometimes afford pure gold. In the clefts, or drains, between the ridges, is found a fine, ruddy earth, beneath which is a lay of blue stony matter, streak'd here and there with yellow; and under this there are pure grains of gold, frequently

* See Boyle Abr. Vol. I. p. 377.

Separation
from its ores.

3. The method of separating gold from its ore, is (1) By roasting it with a reverberatory fire, in order to expel the volatile matters. (2) By boiling it in water, to extract the salt and unctuous part, which will rise and swim on the top. (3) By grinding it with mercury alone, provided it be not unctuous; or if it be, then, (4) By grinding it with mercury and calx of vitriol, and boiling it in water. (5) By means of *aqua regia*. (6) By means of salts which help to fix the consuming volatile, unctuous, or saline part, with which the gold otherwise flies off in the fire, to great loss. (7) By mere lotion with water, which method chiefly obtains in that called gold-dust (e). See

upon
quently of considerable size. To procure the gold, they direct the current of some rivulet hither, to carry off the incumbent earth, and lay the bed of gold bare. This done, they dig up the precious earth, and carry it to the lavadero's, where, by repeated lotion, the earthy lighter part is separated, and the gold left alone*.

"There is also a place in Scotland, where, over a lead-mine, near the surface of the ground, they often find large grains of native gold, free from any spar.—I have," says Mr. Boyle, still a piece of native metal by me, which came from the same place, in weight above forty grains, wherein gold is the predominant metal.†."

"They have work'd in the gold-mine at Crenmitz, says Dr. Brown, now upwards of nine hundred years. The mine is several English miles in length, and about an hundred and sixty fathoms deep.—Of the ore, some is white, some black, red, and yellow. It is not rich enough to admit of any proof in small parcel, to find the proportion of metal it contains; but they pound a very large quantity of it, and wash it in a little river running nigh the place. The whole river being divided into several cuts, runs over the ore continually, and so washes away the earthy parts from the metalline. The common yellow earth of the country all about, tho' not esteem'd ore, affords some gold: and in one place I saw the side of a hill dug away, which had been cast into the works, wash'd, and wrought in the same manner as pounded ore, with considerable profit‡."

It may be added, that gold is sometimes also obtain'd from copper-ore; from tin-ore; from common marcasite, from a red earth, from sand, from German talc, &c.¶.

Methods of separating Gold.

(e) We have observed, that the gold dug out of mines has always some foreign matter adhering to it; particularly sulphur, earths,

and other metals: whence arise several processes, or operations for the separating or clearing it of the same.

1. The first is, to reverberate the mass in the fire; or to lay it on a grate, and there torrify, or roast it, stirring and turning it continually, till all the sulphur be evaporated in smoke. This is performed at the mines by the workmen themselves; and is called *torrifying*, *fuming*, and *separating* gold from the sulphur.

2. After torrifying, and gently bruising the mass, they boil it in water, till it has lost all taste and smell; pouring on from time to time fresh water, and throwing away the old. At length, after a sufficient coction, the water is pour'd out, and the gold remains at the bottom. The matter remaining in the vessel being well dried, they try by cupellation, whether it be gold, or not.

3. If it be not, they grind the mass to powder, and boil it up with mercury and salt for five or six days; and after 'tis ground, boil'd, and elixated, what remains is well dried, and ground with mercury in a large mortar. Upon this, the mercury draws to itself all the gold, and some other metallic matter, it having a peculiar property of uniting to itself either gold, silver, or lead; tin more slowly, copper with difficulty, and iron or stone never. It also joins itself to sulphur: but in this case, the sulphur is supposed all taken away by the first process; and all the salt and oil elixiated by the second. If these were remaining the whole would make a sort of cinnabar; but as they are away, the only impurities remaining, beside silver and lead, are copper, iron, and stones.

4. This being done, the whole mass, mercury and all, is put in a large trough, and water pour'd upon it; and the whole stirr'd briskly about: out of this vessel the water is pour'd into another, where it is stirr'd as before; and out of that poured into a third: by which means the earthy part is kept suspended in the water, and the heavy metallic

part

* Vid. *Diæ. de Com.*

† See *Boyl. Abr.* Vol. II. p. 322.

‡ *Phil. Trans.* No. 58.

¶ See *Boyl. Abr.* Vol. I. p. 59, 157, 158. and Vol. II. p. 324, 325.

upon the head, *Laz. Erker*, Lord Bacon, and the *Philosophical Transactions* (f).

part subsides. This operation they continue so long, and repeat so often, till the water is found perfectly clear.

5. What remains at the bottom, they put in a crucible, or iron vessel, and set it in a naked fire; where, after an intense heat, they find all the metallic matter at the bottom, and the *scoria* at the top.

6. The mass of metal at the bottom, they separate from the mercury, by adding lead thereto, and distilling the whole in a retort; upon which the mercury comes over, leaving only the gold and silver at the bottom: then they pour thereon, either *aqua regia*, or *aqua fortis*; the first dissolving the gold, and leaving the silver entire; and the latter dissolving the silver, and leaving the gold entire. And by such means they are separated from each other.

This is by much the most artful way of getting gold out of the ore; tho' 'tis but of modern invention: had the *Spaniards* been acquainted with it from their first settlement in *America*, they might have saved immensely thereby.

This method is practised by the *Spaniards* in *Peru*; but as the quality of the ore is various, in various places, different processes are to be employ'd. That used at *Schemnitz*, &c. in *Hungary*, is given us by Dr. Brown, as follows:

" They have divers ways of taking the gold out of its ore; by burning the ore, by melting it, by adding silver ore, and other minerals, sand, and lead, as they find the ore fluid or fix'd. Without lead the process is thus: they break, and pound the ore very fine, in water; and then wash it often, and lay it in powder upon cloths, and by the gentle oblique descent of the water over it, and their continual stirring it, the earthy, clayey, and lighter parts are wash'd away, the heavier and metalline remaining in the cloths. These cloths they afterwards wash clean in several tubs; and, after some settling, pour off the water from the sediment, washing the sediment over again, and stirring it up, in several vessels. At length, they sprinkle quicksilver on it, and knead it well together for an hour; then washing it again in a wooden vessel, after separating so much of it as the quicksilver does not touch, by striking the vessel against their leg, they bring the gold and quicksilver together, in an amalgama, to a

Of
corner. From this amalgama they strain as much of the quicksilver as they can; first thro' coarse cloths, and then thro' finer: then put the remaining mass on a perforated plate, which they set over a deep pan placed in the earth; in the bottom whereof they also put quicksilver. This pan they cover, and lute the cover well; then make a charcoal fire on it, and drive the quicksilver, yet remaining in the gold, to the rest in the bottom of the pan. Lastly, taking out the gold, they cast it into the fire, to render it purer."

(f) The ancient physicians say little of any medicinal virtue in gold: the first who mentions it is *Dioscorides*, and that but transiently, and only when speaking of mercury; where he says that gold-filings are a good medicine for such as have taken too much mercury; whence it should seem that he knew gold would amalgamate with mercury. *Pliny* says, gold is a good medicine in many cases; and mentions its virtues in external application. The *Arabians* attribute many virtues to it; *Avicenna* says it is cordial, and of use in the *alopecia*, *serpigo*, and pains of the eyes, heart, &c. but he appears to speak rather from conjecture than experience. The alchemists, however, have carried the thought much farther: they will have this metal contain a radical balm of life, capable of restoring health, and continuing it to the longest period. Gold, say they, has in it a sulphur, perfectly friendly to nature, like that of the sun, which animates the universe: and on such notions they have form'd a thousand chimerical projects, which experiment has always falsified.

What led the *Arabs* and alchemists to imagine such wonderful virtue in gold, was, that they perceiv'd certain qualities therein, which they fancied might be convey'd thereby into the body. Gold, for instance, is not capable of being destroy'd; hence they concluded it must be very proper to preserve animal substances from putrefaction: which is a method of reasoning much like that of some fanciful men, who sought for a pacifying remedy in the blood of an ass's ear, because the ass is a very calm beast.

The alchemists place their hopes in the sulphur of gold; whereas we have a strong presumption, that there is no singular virtue in the sulphur of any metal; since, when that is evaporated, any fat matter, whether of an animal,

animal, or vegetable, will supply its place; and being added to the calx of the metal, will revivify, and give it its pristine form.

Yet gold may still retain some use in medicine. The *aurum potabili*, in particular, is praised, though the attempts to make it so seldom succeed, that many have pronounce'd the preparation impracticable. Mr. Boyle, however, assures us, that he had a *menstruum*, which with a gentle heat would soon bring gold enough over upon a first or second distillation to afford a high, yellow, volatile tincture: But as he could easily recover a malleable gold therefrom, he durst not pretend to do any wonders with it. The

same author observes, that the solution of gold applied externally, may have very considerable effects; and those of a different kind from what it has internally: of which he gives instances in the piles, and venereal disorders*.

To prosecute the *history of gold*, and the other metals in its full extent, would be to write a volume; the subject is so fruitful, as well as curious and useful. In our additional notes we shall rather have a view to a *theory of chemistry*, as defined by the author; for which, however, the nature of our undertaking will only allow us to give a few hints.

ADDITIONS to the Article GOLD.

Gold not only sustains the four capital proofs of cupellation, quartation, royal, and antimonial cementation; but also trituration, and amalgamation, without any decrease of weight.

How allayed, or combined with other metals, and how separated again therefrom.

1. Gold is immiscible in fusion with common salt; many neutral and alkaline salts, mineral sulphur *per se*, lead, and antimony.

2. Miscible with various metals by fusion, as copper, silver, &c.

3. With *regulus* of antimony, or tin by calcination; thence affording a very fine powder, of curious use for staining glass red.

4. A like powder produced by fusing it with a large proportion of tin, and two thirds of lead.

5. Yields an almost irreducible powder upon being calcin'd with iron.

6. A dusky yellow powder procurable by fusing it with thrice its quantity of zink.

7. Separated in *aurum fulminans*, by mixing one part thereof with half its quantity of powdered sulphur, then putting the mixture into an earthen vessel over the fire: thus the sulphur melts, and immediately goes off by deflagration; whilst the remaining calx, not fulminating any more with borax, or any other flux, is now by fusion easily reduced to gold.

8. Separable from iron, copper, tin, or other minerals, by fusing with thrice the quantity of *vitrum Saturni*.

9. Gold and silver separated from each other by quartation.

10. Gold likewise separable from iron, copper, tin, &c. by fusing with a due proportion of *regulus* of antimony and nitre.

11. Untractable gold separated from tin by

the black flux, and by vitrification with *vitrum Saturni*, and nitre.

12. Gold separable from a small quantity of tin, by adding a little mercury-sublimate to the matter in fusion.

13. From particles of an antimonial and arsenical kind, by boiling the matter in an alkaline lixivium, so as to give those particles a degree of fixedness, and afterwards adding nitre, glass, and alkaline salts, whilst the matter is in a gentle fusion.

Its Menstruums, or solvents, &c.

1. Gold is dissolv'd by the condens'd fumes arising from a cautious gradual mixture of the oils of vitriol and tartar. Kunkel recommends this as the best, tho' slowest solvent of gold.

2. Also dissolvable in an *aqua regia* of a particular kind; and in the perpetual fuming spirit of Libavius.

3. In a *menstruum*, prepared of a pound of the phlegm of common *aqua fortis*, and four ounces of sea-salt; the leaves of gold being boiled therein, and the phlegm being afterwards drawn off, there will shoot crystals of a deep red colour, and violet smell†.

4. Gold is likewise dissolvable in a *menstruum* distill'd from oil of vitriol and salt of tartar; and if the experiment be rightly made, this shews the error of the common opinion of the impossibility of dissolving gold, except in *aqua regia*, or a *menstruum* prepared with sea-salt.

5. Dissolved by mercury and heat in amalgamation. And the more frequently this operation is repeated with fresh mercury, and the help of trituration, the easier of fusion the gold becomes. This amalgam, upon being well ground for a considerable time with pure water, or the phlegm of vitriol, affords

* See Boyle Abr. Vol. I. p. 63.

† Vid. Cassius.

fords a black powder, separate from the gold, and a salt of a peculiar kind.

6. By the compound sulphurated salt, made of *sal. mirab.* and wood-coals.

7. By deflagration; one part of gold being mixed with three parts of *regulus* of antimony, and equal parts of nitre, tartar, and sulphur: observing to keep a slow fire in the beginning; to prevent the fusion of the metal, before the sulphur burns.

8. Gold is soon intimately dissolv'd by fusing it with liver of sulphur; so that if a solution of the remaining matter be made in water, no separation of parts ensues; and by precipitation with vinegar, the gold falls, united with the sulphur, to the bottom of the containing vessel.

Its various Preparations.

1. Gold ground with pumice, and afterwards fused with equal parts of nitre, borax, and pot-ashes, affords a fine transparent red glass; a few grains of gold subsiding.

2. Exposed in the focus of a burning-glass, it crackles, and throws off to the distance of seven or eight inches, all around, a numberless quantity of small sparks; which being received on paper, exhibit a powder of entire gold. And the same gold being farther urged, appears to be cover'd with a glassy powder, and smokes as soon as removed from the focus; whilst the remainder that does not go off in fumes, is chang'd into a kind of vitriol, of a violet colour, and less ponderous than gold.*

3. Gold, by a long gentle ignition, is chang'd into a spongy calx, and so far destroy'd, as not to be reducible in the common way, to the same form again. But, previous to this operation, it should be brought into a fine powder, either by amalgamation, solution in *aqua regia*, and precipitation by spirit of wine, or some other fluid.

4. Gold united with other metals, as copper, or silver, by cementation, with a due quantity of nitre, powder of bricks and vitriol, and also verdigrease, or blood-stone; not only becomes porous, and friable, but higher-coloured; especially if a large proportion of any other metal adhered thereto.

5. A powder procurable from gold by calcining it with common salt, hart's-horn, or pumice.

6. Reducible to a calx, by being suspended over burning phosphorus.

7. Into a powder called *aurum fulminans*, by pouring oil of tartar *per deliq.* to a solution of this metal in *aq. regia*, containing *sal-ammoniac*; which causes a precipitation of the metal in the form of a yellow powder.

(1) The gold is thus increased in weight, so as from a dram to weigh four scruples; and no edulcoration will reduce it to its former weight.

(2) This preparation loses its fulminating effect, if too much oil of tartar be used; which may be recovered by pouring spirit of urine, *sal-ammoniac*, or spirit of wine to the calx, and then gently drying it.

(3) A yellow tincture, obtainable by digesting this powder with dulcified spirit of salt; which will still retain its former explosive virtue, after the spirit is drawn off.

(4) This property is destroyed by melting it with flower of sulphur; which being burnt away, leaves behind it a purple crocus. The same effect produced by adding a few drops of oil of vitriol, or spirit of sulphur, whilst it is grinding.

(5) By moistening it with oil of vitriol, and then committing it to distillation, a certain volatil acid salt is procur'd.

(6) A brown calx is precipitated by the addition of a solution of mercury in *aqua fortis*, to that of gold in *aqua regia*.

(7) The same solution, after being diluted with a large quantity of distilled water, and then mixt with a considerable proportion of mercury, is in time, by frequently shaking them together, gradually more and more taken up by the mercury, and a separation of its parts ensues. But if mercury be thrown into a saturated solution of gold, they both subside in the form of a powder, and are not easily separated by *aqua regia*.

(8) This solution is commodiously precipitated by copper; and in order to have this more pure, *Cassius* advises to put crystals of verdigrease, and *Kunkel* vitriol of copper, to a dilute solution of gold. Either way the gold falls to the bottom pure in its native form, and appears of a most beautiful, and higher colour than it usually is *per se*. Whence this method may be esteem'd by artificers.

(9) The same effect ensues upon adding iron to this solution; except that the gold is not so pure.

(10) The same solution greatly diluted by water, and poured into a tin vessel, becomes red; which is the foundation of that beautiful precipitation discover'd by *Cassius*. For if a solution of gold be precipitated by one of tin, prepared after a particular method, the gold will be chang'd into a fine crocus for staining glass of a bright purple.

(11) The addition of wine vinegar, a solution of tartar, or even wine itself to the same solution, will in length of time precipitate the gold, in the form of shining spangles of native gold. *Kunkel*.

(12)

* See *Homburg. Hist. de l'Acad. des Scienc.* 1702.

Of MERCURY.

Mercury, its
characters,
weight,
Simplicity.

1. Mercury is (1) the heaviest of all bodies, except gold, and is so much the heavier, as it is the purer (g).

(2) It is the most simple body (b); being perhaps, when well purify'd, even of as simple a nature as pure gold (i).

(12) The same, after having stood a while with oil of juniper, lets fall the gold in the form of shining leaves.

(13) By only drawing off the menstruum wherein the gold is dissolved, a powder or crocus will be left behind, which being gently ignited becomes of a purple colour. And upon repeating this operation thrice, always pouring fresh *aqua regia* to the calx, and at last reducing it to the consistence of oil; then dropping oil of tartar *per deliq.* thereon, it will be deprived of its fulminating quality, so as to admit of having the liquor safely drawn off to dryness; when, afteredulcoration, a purple crocus may be thence procured, capable of staining glass in a beautiful manner.

8. A black crocus, serving for the purposes of gilding, is obtain'd by dipping clean linnen cloths in a solution of gold, made with six times its quantity of *aqua regia*; afterwards drying, calcining, and reducing them to powder.

9. Tinctures are supposed to be prepared of gold; a potable gold is also made: but these are no other than solutions of this metal.

10. There is also an extraction of gold, and an elegant trituration of gold, mentioned by *Langelot*.

11. The *Chinese* and *Japanese* are said to have the art of softening gold and iron: so as to make them take any impressions, like wax; and of restoring these metals afterwards to their former hardness. Such a discovery, were it real, would be valuable on many accounts.

12. Gold may be subjected to calcination, by means of mercury.

Its Uses.

1. Its use in medicine is trifling; being rather directed by way of ornament, than for any great virtue.

2. Its mechanical, chemical, and economical uses are many.—Upon being added to volatile subjects, especially mercury and volatile gold, they are thereby sooner fix'd. Its uses in coin are as obvious, as advantageous: it likewise serves *per se*, or by its preparations, to form various kinds of utensils, to be wrought in cloths, to gild other metals, and even glass itself; in enamelling, by means of

a golden purple crocus thence obtain'd; likewise in painting, and staining of glass.

(g) From the tables of specific gravity it appears, that there is no body of an intermediate weight between gold and quicksilver. And still the purer mercury is, the heavier it is found; whence some philosophers hold, that mercury perfectly pure, and purg'd of all its sulphur, would exceed the weight even of gold itself. The ordinary proportion, we have observed, is that of 14 to 19: if any mercury be found to weigh more than according to this rate, it may be suspected to have gold in it.

(b) Accordingly we find it the same in all its parts, so far as our observation goes: if a single grain thereof be dissolved in spirit of nitre, a proportionable part of the grain will be distributed into every minute particle of the spirit: and by diluting the whole with a solution of sea-salt, the whole grain of mercury will be recover'd.

Had we the mercury of the philosophers so much talk'd of, called also *vital mercury*, *mercury of metals*, &c. 'tis asserted we should find it still vastly simpler even than gold: for, from gold, we can sometimes separate mercury, and sometimes sulphur; but from pure mercury, nothing beside itself can be separated.

This great simplicity of mercury, has made it pass among chemists, for one of the simple, primary elements of bodies; and even *M. Homberg*, who considers an element, or principle, in a stricter sense than many of the rest, *viz.* as a body which cannot by any analysis be reduced into simpler parts, treats mercury as an element; not that he thinks it uncompound, but because the method of analysing it has not been yet discovered. What puts its composition almost past question, is, that it may be destroy'd, *viz.* by converting it into a perfect metal, and then exposing it to a large burning-glass: whereas an element or perfectly simple body, 'tis universally allow'd, must be absolutely uncorruptible, unchangeable, &c.

The same author endeavours to shew, that the perfect metals are only this mercury, having its particles, or globules, pierc'd on all

(3) It is totally volatile in the fire, being found to fly off in form of *Volatility* fume, by a degree of heat not much stronger than that of boiling water (*k*).

(4) It is no way ductile under the hammer (*l*), but divisible with small *Not malle-* force, into very minute parts, and the more so, as it is the purer (*m*); nor is *ble* it capable by any known degree of cold, of coalescing into a solid mass. May it not hence be suspected for a kind of fluid gold (*n*)?

2. (5) It unites the most readily with gold of all metals, next with lead, *Union with* next with silver, and next with tin; more difficultly with copper, and scarce *metals* at all with iron (*o*). May we not hence argue that it readily unites with the

mercury

all sides, and filled with the matter of fire, or light.

Mercury, therefore, may be considered in three different states: the first, in its form of a running mercury; the second, when reduced into a metal; the third, after the destruction of the metal. In the first state it consists of little solid smooth globules. In the second, of those same globules perforated on all sides, by the rays of light lodged therein. In the third, of the same globules perforated on all sides, but the perforations left vacant, and by the passing of so much light thro' them, during the destruction, so enlarged, as to run into one another, and thereby leave the mercury little else but mere earth*.

(i) Gold is said above to be the simplest of all bodies.

(k) In effect, it does not sustain the fire long enough either to boil, or ignite: tho' it must be added, that if the fire be at first very gentle, and increased by easy degrees, it may be retained therein a considerable time; and be fix'd, so as at length to ignite in the crucible: as we learn from some very tedious experiments made at *Paris*. The gilders are but too well acquainted with these fumes of mercury, which frequently render them epileptic, or paralytic; and they sometimes salivate; being of so penetrating a nature, as to take away scirrhus tumours; tho' very apt to reach, and destroy the nobler parts.

(l) If ductility therefore be made essential to a metal, mercury is no metal; but we should always remember, that definitions are arbitrary, where natures are unknown.

(m) Its parts separate, and recede from each other by the smallest force; consequently, of all bodies, it is that whose parts cohere the least, or are the least tenacious; and therefore, of all others, the least ductile and malleable. The parts of water do not divide so readily as those of quicksilver; and the parts of oil much less: there is a certain tenacity, even in the parts of spirit of wine, which re-

sists a separation; but there is scarce any cohesion at all, in the parts of mercury. If you take, for instance, a single grain thereof, lay it on a looking-glass in dry weather; and in a place not dusty, and apply a lens thereto, which only touches it in one point; the grain of mercury will fly into a thousand globules; each of which, upon the least touch of the lens, will again fly into a thousand lesser globules, and so on, past comprehension. And yet all these globules, tho' infinitely reduced, remain unchang'd as to specific weight, opacity, and separability. The particles of mercury view'd with a microscope, appear perfectly smooth and polite, and reflect objects: so that looking on them, you see all the circumjacent bodies, as in a mirror.

Mr. Boyle proposes the applying a microscope to the minute particles of mercury; by means whereof, a globule, invisible to the best eye, will afford an agreeable and distinct prospect of all the neighbouring objects†.

The third property of mercury, which indeed depends on the second, is, that of all bodies it is divisible into the minutest parts. Thus, being exposed to the fire, it resolves into a fume scarce perceivable to the eye; but in whatever manner it be divided, it still retains its nature, and is the same specific fluid: for the vapours of distill'd, or volatiliz'd mercury, receiv'd in water, moist leather, or the like, become pure mercury. And if mercury be mix'd with other bodies, in order to fix it, (for it is scarce fixable of itself) it is easily separable from them again, by fire; and reducible into as pure mercury, as before.

(n) We have been assured, that the author had fluid gold; and solid quicksilver in his possession. The fact may deserve to be enquired into.

(o) The adepts talk of making an amalgam with mercury and iron; but the experiment would never succeed with us. It is possible there may be some way of binding those two bodies together; and, no doubt an

* See Homberg, on the principles.

† See Boyle Abr. Vol. I. p. 202.

mercury which makes the basis of metals, by some affinity of nature therewith; and this the readier where there is a greater quantity of mercury, and less of a foreign matter in the metal?

*Dissolution.
Difficult to
turn to gold.*

3. (6) It dissolves in *aqua fortis* and *aqua regia* (p). Hence appears the difficulty of converting mercury into gold; since in order thereto, we must give it new weight, fixity and ductility; and yet of all bodies, its nature comes nearest to that of gold.

Where found.

*In what
form.*

4. At this time the greater quantity comes from *Friuli*; where it is found; (1) In a hard stony ore of the colour of *crocus metallorum*. (2) In a soft earth, which contains it pure and running. (3) In roundish stones. (4) And in some places, in cinnabar (g).

amalgam might be made, by adding a large quantity of gold to the iron: but then, if the compound were beat to powder, the iron would wash away in water, and the gold remain. On this account it is, that such as have occasion to work with quicksilver, always make choice of iron instruments for that purpose.

Mercury, in adhering to gold, we observe, renders it humid: thus we have known women in a salivation have their ear-rings grow white, and soft with the mercury. And hence the gilders, to lay gold on any other body, dissolve it in hot mercury; which done, they apply the solution on the body to be gilt, suppose silver, then setting it over the coals, the mercury flies away, and leaves the gold adhering like a crust, to the silver.

It may be added, that mercury is a fluid which adheres to no body, but metalline ones; unless driven thereto by force of attrition, as in *æthiops mineral*, where by a long incessant rubbing, mercury and sulphur are made to mix. And hence mercury is called, the "water that wets not the hands."

(p) It dissolves in almost all acids, and unites itself with them: at least, with all mineral acids. Thus we find it dissolve in oil of vitriol, spirit of nitre, and *aqua regia*. It is united with oil of vitriol into *turbith mineral*, with *aqua regia*, or spirit of sea-salt, into corrosive sublimate. Yet vinegar does not dissolve it; and hence we are furnished with a method of detecting the frauds of druggists, &c. who make a practice of sophisticating quicksilver with lead. For grind the mercury in a mortar with vinegar; and if the vinegar grows sweetish, 'tis a proof the mercury is mix'd with lead: if it have been adulterated with copper, the vinegar will turn greenish, or bluish; but if unadulterate, the mercury and vinegar will both remain without alteration.

* See *Boyle Abr.* Vol. p. 597.

5. The Some add, as a further property of mercury, that of all fluids it is the coldest and the hottest, supposing the circumstances alike. This property depends on the great weight of mercury: for the heat and cold of all bodies, is, *cæteris paribus*, as their weights: now, mercury being fourteen times heavier than water, if both of them be exposed in a winter's night to the same cold, the mercury must be so much colder than water, as it is heavier. So, also, if they be both applied to the same degree of heat; while the water is barely warm, the mercury will be hot enough to burn the hands. Thus, in spirit of wine, we perceive a slight degree of cold; more in water; and most in mercury.

Notwithstanding mercury receives such a degree of cold, its great separability and fluidity prevents its congealing. Mr. Boyle tried various ways to bring it to freeze by making an extreme cold, and exposing an exceedingly thin skin of mercury thereto; but without effect *.

Others add, as a property of mercury, that it is free of all sharpness or acrimony. It shews no acrimony to the taste or touch; but the extraordinary effects it produces in the body have given rise to a notion of its being acid; but the case is otherwise: when receiv'd into the blood, it only acts by the weight and velocity of its minute particles; by which momentum it tears and destroys the vessels, and thus occasions those great alterations falsely attributed to acrimony. In effect, all its medicinal operations are to be accounted for from the properties already enumerated.

The form wherein Mercury is found.

(q) The greatest part of our quicksilver is brought from *Friuli*, where there are abundance of mines, belonging to the emperor: it is there found under three several forms. 1. In ruddy glebes, or red mineral stones called cinnabar. 2. In hard stony glebes, or substances

of

5. The method of separating it from the ore, is either by distillation, or *Separation* by lifting and washing it with water. What is found native in the mines *from its ore* without fire, is called *virgin mercury* (r).

of a saffron, and sometimes a blackish colour. 3. It is also found pure; for, upon opening holes in the beds of stones, &c. there sometimes gushes out a stream of pure mercury, call'd *virgin mercury*. This last sort is the most valued. *Paracelsus* and *Basil Valentine* prefer it to any other sort for chemical operations.

Mercury is either found in its own proper mines, or in those of other metals, where-with it is intermixed: besides the mines of *Friuli*, there are considerable ones in *Hungary* and *Spain*. The earth or matter it is found in, is different in different places: In the *Spanish* mines 'tis ruddy, streak'd with black, and so hard that there is no digging it without gun-powder. That of the *Hungarian* mines is sometimes a pretty hard stone, but more usually a dark-coloured earth, inclining to red: In the mines of *Friuli* there is a softish earth, wherein *virgin mercury* is found in little drops; and a hard stone that yields the common mercury.

Mineralists generally distinguish another sort of *virgin mercury*; for the denomination is common to all mercury procured without fire. This latter is what is separated from the earth by washing with water, and passing thro' several sieves.

Manner of separating Mercury from the Ore.

(r) First, they grind the mineral glebe into powder; which done, they pour a great quantity of water upon it, stirring, and working the whole briskly about, till the water becomes exceeding thick and turbid: this water having stood to settle, they pour it off, and pour on fresh, which they stir and work as before. This they repeat, till the water, at length, comes away perfectly clear. Then,

ADDITIONS to the Article MERCURY.

Hints for its medical History.

1. It readily unites with bismuth, as well as lead, and is thus often adulterated. When mercury is used in medicine it ought to be pure. The straining it through leather is not sufficient; for thus it may carry lead and bismuth along with it. One of the best ways of purifying it seems to be by grinding it in a glass mortar, with vinegar and a little salt; which dissolves and frees it from metallic impurities: tho' it should rather be distill'd from quick-lime, fix'd alkali, or iron-filings,

all remaining at the bottom of the vessel is mercury, and other metalline matter. To this mass they add the filings of iron; then, putting the whole in large iron retorts, distil it; by which means all the heterogeneous metallic and stony part is separated therefrom, and the mercury brought over pure.

The most expeditious and advantageous manner of separating quicksilver from its ore, when rich, is this. They first beat the mineral to powder, then put it into earthen vessels, like long-necks, or bird-bottles, the narrow mouths whereof they stop with moss; then inverting their necks into the mouths of similar earthen vessels, that lie buried upright under ground, they lute them, and make a fire round the upper vessels, which causes the mercury to distil *per defensionem* into the receivers that lie cool below. But when the ore abounds with sulphur, it requires the addition of lime, pot-ash, or iron-filings, to make the mercury separate, and distil off.

The *virgin mercury* ordinarily needs nothing to purify it, but a washing in common water: though, sometimes, it is so full of an arsenical matter, that they are oblig'd to strain it thro' a skin; and sometimes there is an earth united with it so strongly, that they are obliged to have recourse to distillation.

As to the mercury in pure cinnabar, they don't find it worth while to distil, and get it out; such cinnabar selling for a better price than mercury itself.

The miserable people condemn'd, or hired to work in these mines, all die in a little time: they are first affected with tremors, and proceed to salivate; then their teeth drop out, pains seize them all over, especially in their bones, which the mercury penetrates.

for fear of any antimonial or arsenical particles adhering to it. It is allowed to be pure, when a little of it held over the fire in an iron ladle, totally evaporates.

2. Quicksilver was anciently rank'd among poisons. *Dioscorides* reckons it pernicious, and *Galen* highly corrosive. It is not mention'd by *Hippocrates*. *Mesue* recommends it only in cutaneous diseases; tho' *Avicenna* observes it might be safely swallow'd, and pass'd thro' the body unchang'd. *Jacobus Carpenfis*, an eminent surgeon and anatomist at *Bologna* in

Of LEAD.

Lead, its characters.

Weight.
Simplicity.
Volatility.

Softness.

Fusibility.

Its glass very penetrable.

1. Lead is (1) the heaviest body after mercury (s).
(2) It proves extremely simple in all kinds of trials.
(3) It is not fix'd, but fumes in the fire; and after continuing long in fusion, penetrates most of the vessels hitherto used.

(4) It is the softest of all metals, easily ductile, and the least elastic, or sonorous (t).

(5) It melts the soonest of all the metals, except tin; even long before it ignites, and thus grows scurfy, readily vitrifies, and being now fus'd, it passes through any vessel (u).

(6) It throws up light bodies that are cast into it; vitrifies with the baser metals, and having so done, carries them along with it from the cavity of the test; thus leaving only gold and silver behind, separated from the rest. After fusion,

Italy, seems to have been the first who used it in venereal diseases. The medicinal virtues of it, and its various preparations, are now generally known.

Hints for its alchemical History.

The analysis of quicksilver is extremely difficult, on account of its great volatility; yet by degrees it may be brought to sustain a considerable heat, without losing, nay even encreasing in weight; as in making the precipitate *per se*; which, being gently heated in live charcoal-dust, like the calx of a metal, returns to quicksilver. This precipitate exposed to the focus of a burning lens, upon a proper support, melts into a matter like glass, and afterwards evaporates, leaving a little brown powder behind, which vitrifies upon being further urged. But if supported by charcoal, it first turns to glass, runs on the coal, and turns to quicksilver again; whence it should seem to consist of a volatile, vitrifiable earth, and a sulphur; and if so, this might give it a claim to a metallic nature. See M. Homberg, Mr. Boyle, and Dr. Stahl upon the subject.

(s) Hence melted lead constitutes a fluid of the third order of gravity; wherein all bodies, whether metalline, or not, excepting gold and mercury, might float, if there were no other cause to the contrary.

If all the impurities of lead could be perfectly purged away, its weight might nearly approach to that of mercury. Accordingly, in analyzing this metal, it is said to yield a considerable quantity of mercury; tho' what the other ingredient is, united with the mercurial part seems hard to say. Lead, tho' a cheap and common metal, has yet a great affinity with gold; at least in point of weight,

which seems to be the most distinguishing, and immutable character of gold: and hence it proves the resemblance still closer, is, that lead does not mix with any metals except those allowed to be mercurial ones.

(t) There is no metal whose figure is so easily changed as that of lead: and hence it proves very ductile, and easily flexible; tho' not capable of being drawn out into such simple, fine coherent parts as gold.

It diminishes the sound of other metals, when mixed therewith. This property follows from its softness: for if two equal leaden balls be struck with equal velocities against each other, they will both remain fix'd in the point of contact, without any vibration, or resiliency; so that of course no sound can be produced. 'Tis on account of this unelasticity of lead, that it has been used by Dr. Wallis, M. Huygens, and others, for determining the laws of percussion. By this property also, lead should appear to be nearly allied to gold, which is the next least sonorous, or springy of all metals. Accordingly, several Experiments have been produced, to prove that lead melted, always either contains, or generates some portion of gold. M. Homberg assures us, that taking a quantity of silver, and separating it from all heterogeneous matter by testing with lead, then putting a piece of it in *aqua fortis*; a little gold fell to the bottom. And upon adding copper to the *aqua fortis*, the silver was precipitated.

(u) A quantity of lead being set over the fire in an iron ladle, no sooner begins to run than its surface appears exceedingly bright, and shines like mercury; but its face soon alters, and you discern a cloud therein which gradually increases, till the whole surface appears darken'd with a dusty Scoria: this dust being

fusion, it quickly returns in the cold to a solid mass, tho' more slowly than tin (x).

(7). It dissolves in *aqua fortis*, not in *aqua regia*, and thus yields a sweet Dissolution. salt (y).

2. It is found plentifully in various mines of *Europe*; being cheap, and the consumption of it large: but 'tis in its nature very surprizing, and for certain purposes exceedingly useful. In the fabulous way, it is called the origin and father, as well as the devourer of other metals. Found in plenty.

3. Its ore is usually ponderous and shining; of a lead colour; which yields more than half the quantity of metal. Sometimes it is white, red or yellow, which are poorer kinds; it often contains a little silver, by which the assayers, if not on their guard, are apt to be deceived (z).

being blown away with bellows, there strait arises a new supply; and so on, till the whole lead is thus converted into *Scoria*, which are only the matter of the lead gently calcined. A more violent fire vitrifies them, that is, converts them into a heavy, brittle, pellucid, elastic, sonorous matter, called glass; into which other metals are indeed convertible, but lead the easiest; and which is of such a penetrating nature, that it runs thro' all the common crucibles, almost as water thro' a sieve.

The calx of lead has nothing of the appearance of lead; and yet, by only exposing it to a strong fire, and adding a little iron filings, or any unctuous inflammable matter, the lead is easily recovered.

And if while the lead is in fusion, it be kept continually stirring with a spatula, it turns into a red powder called *Minium*, or red lead: in which operation this is farther observable, that the lead augments in weight.

(x) It dissipates all metals tested with it, on the cupel, except gold and silver; which is a property, that had we been unacquainted with, all our treasures of gold and silver had

lain in little compass: this being of principal use in the obtaining those metals.

The foundation of the process is this: any mass, of what kind soever, whether metal or stone, salt or sulphur; gold and silver only excepted; being mixed with lead and exposed to the fire, separates and flies off.

Upon the whole, there are three ways, whereby all the matters mixed with gold and silver are destroyed, and lost, when cupel'd with lead: 1. By volatilizing, and evaporating. 2. By turning to *Scoria*, and retiring to the sides of the test. 3. By penetrating the pores of the cupel; which only happens to such bodies as can neither fly off in fumes, nor work to the sides in the way of *Scoria*.

(y) It dissolves in most of the weak acids; but very difficultly in the stronger, unless they be diluted with water. Thus, in *aqua fortis* it dissolves slowly; but very readily in vinegar, small *aqua fortis*, *Renish* wine, spirit of vinegar, &c. and even in oil of vitriol, well diluted with water. Add, that in whatever acid it is dissolved, the solution becomes considerably sweet, like sugar. The fumes of wine or vinegar dissolve it into a white powder, or calx, called *Ceruse*, or white lead.

SUPPLEMENT to the Article LEAD.

The name.

(z) The *Greek* authors frequently use the same name to express both lead and tin; and accordingly, their *Latin* translators interpret *καρσιπες* both by *plumbum* and *stannum*. *Geo. Agricola* mentions three kinds of *plumbum*, one white, which we call tin, another of an ash colour, which we call *bismuth*, and the third livid, which is our lead.

The forms of its ore.

Lead is seldom found pure in the mines, and has different coloured ores, viz. black, yellow, and ash coloured; it is also found in

red, or white rocky stone, and sometimes in the form of dice; when shining lead-colour'd surfaces; and sometimes mix'd with white, yellow, or green fluors. There are many lead mines in *Spain*, *Italy*, and *Germany*; but the richest are those of *England*.

Its poisonous nature.

The ore is of a poisonous quality, especially with regard to brutes: "They who live near where it is washed," says Mr. *Beaumont*, "can neither keep dog, nor cat, nor any sort of fowl; but they all die in a short time." He adds that "not only calves, but even chil-

"dron

"dren have been known to be killed, by
"only being in houses where lead-ore had
"been kept some time; and that if any sort
"of cattle feed often on the grass on which
"the steam which rises from the smelting of
"lead falls, they all die soon after *."

Differences of its ore.

There is a very considerable difference between the ores of different mines: some is so like steel, that the workmen call it *steel-ore*; which being of more difficult fusion than ordinary, they mix other ore with it. There is another, which from its aptness to vitrify, and its use in glazing the potters vessels, is called *potters-ore*.

Our *English* lead-ores are reducible to three classes: the first, those which in the ordinary ways of melting afford from thirty to forty pound of metal, for every hundred weight of ore. The second, from forty-five to sixty. The third, from sixty to eighty.

Contains silver.

The lead found in some parts of *England*, contains from five to ten pounds of silver in a tun weight; which they get out by testing, and recover the lead without any great waste.

The lead of many mines being skilfully treated, affords silver; but the quantity of silver in the ores, does not hold in proportion to the quantity of lead. Mr. Boyle caused some lead-ore to be tried, which being the most promising he had ever known, gave him hopes of some considerable quantity of silver: but tho' it proved so rich in lead, as to afford after the rate of seventy pounds to the hundred; yet one of the most expert artists in *Europe* could not extract one grain of silver from it. Yet a piece of lead-ore was brought from *Ireland*, which seem'd so light in the lump, that he thought it scarce deserved to be wrought for lead; which, however, was found upon trial, so well stored with particles of silver, that he encouraged the owner of the mine to work it.

How smelted.

Some lead-ore requires no previous preparation to its being smelted, unless by grinding. They barely throw it upon a wood fire, or a forge hearth, where the metal running into a basin in the hearth, they ladle it out, and cast it into an iron mould, which gives it the form of what we call *pigs*.

In the lead-works at *Mendip* in *Somersetshire*, the method of procuring the metal is thus delivered by Mr. *Glanvil*. "When they
"have got the ore, they beat it small, then
"wash it clean in a running stream; and
"then sift it in iron rudders: then they make

"a hearth, or furnace of clay, or fire-stone,
"and therein build their fire, which they light
"with charcoal, and keep up with young
"oaken gads, blown with bellows. After
"the fire is lighted, and the fire-place hot,
"they throw the lead-ore on the wood, which
"melts down into the furnace; and then with
"an iron ladle they take it out, and cast it in
"sand, into any form they please†."

Its medicinal virtues.

Both in its crude state, and in all its preparations, lead seems to be cooling, thickening, repelling, absorbing, and contracting; so as to retard the circulation of the blood, hinder all the secretions, and hurt the nerves; by causing spasms, convulsions, tremblings, difficulty of breathing, and suffocation: whence it appears unfit for internal use in any large dose; and, accordingly, its medicinal uses are chiefly external.

Its other uses.

Its uses in the hands of the plumber, glazier, shot-maker, white and red-lead maker, potter, assayer, jeweller, painter, &c. need not be mention'd, as being commonly known. A mixture of it with tin is the foundation of enamelling; and counterfeit gems are made by its means.

Hints for its alchemical history.

Let the *Saturnus cornuus* be examined for mercurification.

What vessel will hold the glass of lead in fusion?

Let the talky nature of litharge be examined.

As lead fulminates with nitre, and flashes in the flame of a candle, and burns blue, it may seem to contain a sulphur.

Is not the sulphureous principle in lead small in quantity, and but loosely join'd; since a small degree of fire is able to separate them?

Expos'd upon a tile to the focus of a burning glass, it fumes, and turns to a yellow or red calx; then melts into a yellow fluid, which soon evaporates in smoke; but if removed before this happens, it hardens to a yellow mass like orpiment, consisting of *Laminae* like talc. This being again expos'd to the focus, on a piece of charcoal, recovers the form of lead. But if the lead be laid upon charcoal, it thus totally dissipates in fume, and leaves no glass behind. Hence what relation has it to mercury, gold, &c?

Is it not compos'd of a soft, talky, vitrifiable earth, and a small proportion of a sulphur, or inflammable substance lightly join'd therewith?

* *Phil. Collect.* N°. 1.

† *Phil. Trans.* N°. 39.

Of SILVER.

Silver, its
characters.

Weights.
Simplicity.

1. Silver is (1) the next in weight to lead (a).
- (2) Very simple, nor discovers the least diversity of parts, by any ordinary means.
- (3) Fix'd in the fire, so as, when pure, scarce to lose any thing thereby. Fixity.
- Having been kept two months in a state of fusion, in the eye of a glass furnace, scarce $\frac{1}{10}$ part of its weight was found wanting. And it may even be doubted whether it had then been totally purified first (b).
- (4) It is malleable and ductile into very fine wire (c).
- (5) It ignites and fuses at the same time (d).
- (6) Dissolves in *aqua fortis*. (e).

Malleability.
Fusion.
Dissolution.

(a) Being to that of gold as 10 to 19; and to that of water, as 10 to 1. It falls short, therefore, of mercury, and consequently is but little disposed to become gold; unless we had a method to make it much denser, and more compact. And hence it is that the alchemists hold it more easy to make gold of mercury, than of silver; and laugh at novices for attempting to convert silver into gold.

(b) It is so fix'd, as in this respect to exceed all the known bodies, except gold.

This appears from an experiment of the Prince of *Mirandula*, who placing a quantity of silver in the eye of a glass-furnace, kept it in continual fusion for the space of two months; then taking it out, found it to have lost only $\frac{1}{10}$ part of its weight. Mr. *Boyle* assures us from experiments of his own, that silver set in the eye of a glass-furnace, scarce loses any thing of its weight. But is highly probable, that the silver used in these experiments was not pure; nor perfectly purged of tin: for Mr. *Boyle* taking out his silver at a fortnight's end, found it to have lost something: but after that, tho' exposed a long time to a very violent fire, he could not perceive it to have lost any thing at all; the tin, which is exceedingly difficult to separate from silver, having been all carried off by the first fire.

Mr. *Boyle* likewise observes, that tho' silver be one of the most fix'd of all bodies, it may be possible, by a mere change of texture, to render it volatile. To confirm this, he instances a calx of silver made by a solution of the metal in a peculiar menstruum, which, to his great surprize, upon exposing it even to a gentle heat, presently flew away in form of a *Parina Volatilis*, whitening the neighbouring part of the chimney, &c.

(c) Yet it is the most ductile and malleable of all bodies after gold. Our wire-drawers

stretch out silver to an incredible fineness; thus, for instance they will draw out a single grain into a thread of nine yards long; which thread is still capable of being beat into a leaf two inches broad, and still cohere.

(d) It pretty readily melts in the fire; much more easily than either copper or iron, tho' more difficultly than either gold or lead; and runs as it begins to ignite.

(e) It is dissolvable in *aqua fortis*; and not in *aqua regia*.

Aqua regia we have already described, with all the species thereof; and have shewn that sea-salt is the basis of them all. *Aqua fortis*, on the other hand, is always made of nitre; nor is silver dissolvable in any saline menstruum, except what has nitre in it: not in sea-salt, nor spirit of sea-salt, nor *aqua regia*, nor oil of vitriol, nor sal-gem, nor sal-ammoniac nor spirit of sulphur *per campanam*, nor spirit of alum, nor vinegar, nor any other acid, or alkaline salt or juice. In effect, sea-salt, sal-gem, and sal-ammoniac are the only dissolvents of gold; and nitre the only dissolvent of silver.

If sea-salt, or sal-ammoniac be added to spirit of nitre, it will no longer dissolve silver, but gold: and hence, if you would try whether *aqua fortis* be pure, put to it a small quantity of pure silver; and if now the solution remains without turning milky, or the silver's being precipitated, you may be assured the *aqua fortis* is pure; for if it had the smallest grain of sea-salt, or sal-gem, the liquor would become milky, and the silver fall to the bottom. Here seems therefore to be a sort of natural repugnance, which is found of the utmost use; in regard that without it we should want a method of separating gold from silver: 'tis true, they may be separated by antimony; but then the silver all flies away, and is lost; and as for lead, it only separates every thing else

* See *Boyl. Abr.* Vol. I. p. 372.

Purification. (7) It is purify'd with lead, and sustains the same (*f*).

(8) Turns to *Scoria* with antimony, and becomes volatile (*g*).

Where found. 2. It is found in many places, and in different kinds of ores; having almost universally a little quantity of gold in it (*b*).

else from gold and silver, leaving them together as it found them: but dissolve a mass of gold and silver in spirit of nitre, and what falls to the bottom is gold, and what is retained is silver; or dissolve it in *aqua regia*, and what falls to the bottom is silver.

M. Homberg had the fortune to discover, by a happy mistake, that *aqua regia*, under some circumstances, will dissolve silver, and not gold. The phlegm which arises first in distilling *aqua regia*, he observes, is a true *aqua regia*, and yet this, if taken when newly made, and after it has been some time in digestion with gold, will dissolve silver, and not touch gold; tho' without these two circumstances, it has the contrary effects*.

M. Homberg likewise has discovered a new way of separating gold and silver; viz. by putting the mass in a crucible, with equal parts of salt-petre, and decrepitated salt at the bottom thereof, and setting the whole to fuse in a melting-furnace, by a gentle fire, for the space of about a quarter of an hour.

The effect, he accounts for, by supposing the salts, before they are perfectly fus'd, to sustain the mix'd metal, when it begins to melt and serve as a kind of sieve to it, letting the heavier part, the gold pass thro', and retaining the lighter, the silver, which does not fuse so soon. So that if the crucible be taken from the fire at the proper juncture, the silver presently hardens, &c. In the mean time, the salts being but imperfectly fus'd, prevent the silver's falling down, and remixing with the gold†.

(*f*) Thus if 100 pounds of pure silver be fused along with lead; the latter will all evaporate, or be blown away upon the test; and the silver remain behind without any diminution of weight.

(*g*) It does not resist the force of antimony; but volatilizes, and flies off along with it. Whence this should proceed, is not easy to say; antimony we know, is corrosive, to a great degree; so that it volatilizes all metals, except gold; and carries them off in fumes. There is, therefore, a considerable difference between the nature of gold and silver; the former resisting lead, and every thing else; the latter, too, resists lead, but not the lead of the philosophers, viz. antimony. And hence that denomination of antimony, *Bal-neum. Jolius regii*.

* Mem. de l'Acad. 1700

(*b*) Most countries in all the quarters of the world afford silver mines; but *Peru* and *Chili*, above all others: the mines of *Potosi*, in particular, are said to be inexhaustible; being dug now with almost as much success as when at first discovered; abating this, that the vein then lay, as it were, on the surface of the ground, but is now got to a great depth, being descended to by 500 steps.

Silver is scarce ever found pure, and free of all heterogeneous admixture: we meet with it in almost all sorts of minerals; sometimes in the ore of gold, sometimes in that of lead, and that of copper; but ofteneft in a kind of black stony glebes, full of shining streaks. It has a corrosive sulphur, or bitumen, always found attending it; which turns yellow in the fire, and has somewhat of the effects of antimony; and perhaps has some antimonial parts in it; being found to volatilize the silver in the cupel, and steal it a way in fume. The loss in this respect is considerable, especially if the ore be very crude; so that the utmost care is to be had in making the separation: for a mass of this kind being put in melted lead, the sulphur will, indeed, be all carried off: but then the point is somewhat delicate; for if the fire be too strong, the silver is apt to go along with it; and if too slack, the sulphur will be left behind. 'Tis certain, many thousand pounds worth of silver have been evaporated and lost in the separation.

The mineral stones dug out of the mines of *Peru* are of different colours, qualities, hardness, &c. Some are white, or greyish mix'd with red or bluish spots, called *Plata blanca*; others black, called *Plata negra*, which is the richest and the easiest wrought. The *Rosiller*, tho' rich, turns red, when rubbed against iron. The *Zorock* shines like talc. The *Paco* is of a yellow red, extremely soft. The *Cabrissa*, green, and almost friable. Lastly, the *Aranea*, which is found only in a single mine at *Potosi*, consists of threads of pure silver, interwove, somewhat like silver-lace, that had been burnt for the silver.

The working of these mines is exceeding dangerous, on account of the exhalations they yield; which are even felt to a great distance; and not only suffocate the miners, but the cattle grazing in the neighbourhood. Scarce any of the workmen can bear so pestiferous an air above a day together. It sometimes

† Mem. de l'Acad. 1713.

3. To the ore there usually adheres a corrosive, bituminous sulphur, which by its rapacious quality renders the silver volatile, and dissipates it in the fire; or even converts it into glassy *Scoria*, to the great loss of the owner (i). This, which neither salt nor lead will hinder, is however prevented by means of mercury; viz. by roasting the ore, then reducing it to powder, adding mercury thereto, and grinding them long together, so as to unite the silver with the mercury; which are afterwards to be separated again by distillation (k).

Of

times proves so mortal, that they are obliged to stop the mines up again. The mines of *Potosi* are reckoned the most innocent; and yet they say, it were impracticable to work even these, but for the herb *Paraguay*, an infusion whereof, taken as tea is among us, serves as a sort of preservative.

Manner of separating and purifying of silver.

(i) A quantity of the silver glebe, or ore, is first roasted, or calcined in a furnace, by a gentle fire; stirring it from time to time; and taking care the fire be not so great as to melt it, and make the sulphur carry away the silver. The sulphur thus insensibly consumed, they grind the mass into a powder; and throw large quantities of water thereon; taking care to stir and agitate it sufficiently, to separate all the lighter parts, and make them swim a-top. After it has stood a-while to settle, they pour off the water, with all that was sustain'd therein, and pour on fresh: this they stir and pour off as before; repeating the process till all the lighter earthy matters are clear'd away, and nothing left at the bottom but metal, with the heavier stones, &c. To separate these, they put the mass into melted lead, over a fire sufficient to carry off the remaining sulphur, yet not so fierce as to carry the silver along with it; and as mercury has a property of drawing silver to itself, they add a quantity of hot mercury to the melted lead: by which means the whole metallic matter becomes amalgamated, or fix'd in a mass, exclusive of the stones; tho' the sulphur must be well clear'd out in the first place; otherwise the mercury will not attract the silver, but dissolve and mix with the sulphur.

The next step is to dilute and grind this amalgam, or mass of mercury and silver, in water; then they distil it in a retort; by which means the mercury all rises and distils off, and the pure silver remains in a powder at bottom.

In the silver works of *Pern* and *Chili* the method of separating the silver is somewhat different. After first breaking, and then grind-

ing the ore by a water-mill, they sift it in iron riddles, and mix it up with water into a paste: this, after half drying it, they cut out into square pieces of about 250 pound each, called *cuerpos*; and bake them over again with sea-salt, which melts and incorporates therewith. This done, they sprinkle mercury on them, and bake them a third time, till the mercury be well incorporated with the whole substance of the silver. This operation, which is exceeding dangerous, falls to the share of the poor *Indians*, who go to it eight times a day. To promote the effect of the mercury, they add lime and lead, or tin-ore, and, in some places, even make use of fire.

When the amalgamation is completed, they carry the mass to the *lavaderos*, which are three basons placed aslope, so that they empty successively out of one into another: the *cuerpos* being thrown into the uppermost, and the stream of a rivulet turn'd upon it, the lighter earthy part is separated, and carried off; which is forwarded by an *Indian*, all the while treading upon the mass. When the water goes off clear, the silver is found at the bottom, incorporated with the mercury; in which state it is called *pella*. To get out the mercury again, they put the *pella* in wooden bags, press it hard, pound it lightly, and at last full it in a sort of wooden mould, or trough, perforated at bottom like a colander; and now the mass is called *pinca*.

The *pinca* being taken out of the mould, is then laid on a copper-plate full of holes, over a trevet, under which is a large vessel of water; and the whole cover'd with a capital of earth, which they surround with fire. By this means, the mercury remaining in the *pinca*, is first volatiliz'd, and raised; then falls into the water, where it condenses, and thus leaves the silver in grains of different figures sticking to each other. And 'tis in this form the workmen endeavour clandestinely to sell the silver to foreign vessels, trading in the *South-Sea* *.

(k) *V. Philos. Transact.* No. 589, 590, 591

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ADDITIONS

* *Savary Dict. de Commerce.*

The Theory of CHEMISTRY.

ADDITION to the Article SILVER.

Its natural history.

It is found either *native*, or in *ore*. Native silver is often found considerably pure and unmix'd, in the clefts of rocks, or fissures of stones; and frequently adheres to cobalt, which it seems particularly to affect. This native silver is met with, sometimes, in the form of branches, or twigs, and sometimes in that of hair, grains, or leaves. Sometimes also it has been found in lumps, or masses of a very large size.

Silver ore is often red, when it seems to be mix'd with cobalt, which gives it that colour; 'tis also sometimes black, white, purple, green, or grey, according to the matters wherewith it is mix'd: not to mention again, that it is also frequently found in the ores of lead, tin, and copper; and sometimes in a considerable proportion. There are silver mines in several countries, as *Great-Britain*, *Norway*, *Germany*, *Hungary*, *Italy*, &c. but the richest are those of *Mexico* and *Potosi*. The ore is said to be rich if it affords a fifth part of silver.

How separated from its ore.

It is easily separated from lead-ore, by bare testing; and so it may be from the ores of other metals, by means of lead, used in the same manner*. But it requires more labour and address to separate the silver from the *Mexican* and *Peruvian* ores; which are usually not only extremely hard, but also mix'd with bituminous, sulphureous, arsenical, or vitriolic matters, capable of calcining the matter, or carrying off a great part of it in the fire; so that according to the nature of the ore, a suitable method is to be used. When hard and stony, they break it with hammers, and roast it gently, to render it friable; then grind it by the mill, and if the remaining heterogeneous substance be now found to be sulphur or antimony, they mix it with iron-slings; and *vice versa*, if they find it contains iron, they add antimony or sulphur; and thus calcine the whole together; then grind it with quicksilver; which will now unite with the metallic part, whether gold, silver, tin, bismuth, or lead: but if the baser metals thus mix with the quicksilver, they cause it to run sluggish, and with tails; whence the operator is directed how to treat the mass, by lotion, percolation, distillation, and fusion, with or without adding the calx

of copper, or other metals thereto. The best way of rendering silver perfectly pure is, perhaps, after cupellation to fuse it well with nitre and borax, and repeat the operation till it will no longer turn these salts green †.

Its virtues and medicinal uses.

The chemists and chemical physicians have attributed extraordinary virtues to silver, which are not warranted by experience; and yet they have had the success to introduce it into medicine under various shapes. Some preparations of it, however, may have great effects; as the *lunar pills*, the *lunar crystals*, and the *lunar canalic*; tho' perhaps their efficacy depends as much upon the menstruum as the metal: but for the *lunar tinctures*, if made of pure silver, without any mixture of copper, we know of no great virtues they are possess'd of.

Its other uses.

Its use in the way of coin, plate, vessels, ornament, &c. need not be mention'd. When perfectly pure, it yields but a small soft sound; being less sonorous than iron and copper, tho' more than gold; but if mix'd with copper, it becomes harder, more sonorous, yet preserves a great degree of ductility: whence appears the great utility of its alloy. Its being harder, yet lighter than gold, may fit it for several purposes where gold might be improper. In chemistry, 'tis used for imbibition, corporification, and confirmation of the subtle atoms of gold and silver.

Hints for its alchemical history.

It loses of its sound and colour by being mix'd with lead; 'tis render'd brittle by tin; more fusible, and volatile by antimony; and is strangely affected, or demetallized, by burning silver. How is it affected by phosphorus? Will a gentle treatment of it upon the test with *regulus* of antimony, or a proper cementation with *crocus metallorum*, obtain any gold from it; and if so, how much?

Silver, exposed to the focus of a large burning-glass crackles, emits a copious fume, and is at length cover'd pretty thick with dust, or calx; which dust, if the silver have been refin'd with antimony, is of a yellowish hue; and by the further action of the solar fire, will vitrify like gold: but if it have been refin'd with lead, the calx proves whiter, and never vitrifies †.

* See the article LEAD.

† *Mem. de l'Acad.* 1702.

† See the article GOLD.

Of COPPER.

1. Copper (1) is in weight the next to silver (l).
- (2) It is simple, tho' less so than the preceding metals.
- (3) Considerably fix'd in the fire, yet fumes and is in part volatile (m).
- (4) Ductile under the hammer, and may be drawn into fine wire; being also very elastic, and yields a tinkling sound (n).

Copper, its
characters.
Weight.
Simplicity.
Fixity.
Ductility.

(5) Ignites before fusion, and melts with more difficulty than all the other metals, except iron; when melted it makes a strong opposition to cold water, the pouring of a little thereon being of terrible consequence (o).

(6) Easily dissolves with any salt, and turns green, or blue, but readily lets go its solvent, and losing its former beautiful colour, becomes an unsightly dirt. And thus in the air, or water, it shoots into efflorescences, and thence into little crystals (p).

(7) It readily turns to *Scoria* or glass with iron or antimony, and flies off in fume, upon the test, or thro' the pores thereof.

2. It is found in mines, in all countries; and adheres so strongly to its stone or ore, as frequently to require fourteen fusions before it becomes pure (q). Its ore often contains silver, especially the black and bluish ore; the yellow, green and brown having a less share. In its veins are also frequently found

Where found.
Its ore.

(l) The first character of copper is its specific gravity; which, as already noted, comes next to that of silver; being to gold as 8 to 19; to water as 8 to 1, and to silver as 8 to 10.

(m) It continues long fix'd in the fire, before it flies off; or much longer than lead or tin: tho' at length it loses much of its weight; being much more difficult of fusion than silver, and igniting before it fuses.

(n) Of all the unmix'd metals it is the most elastic and sonorous; and on that account is commonly used for the strings of musical instruments, trumpets, bells, &c.

(o) It must be remember'd that if, when copper is fused, a single drop of water do but fall upon it; or if the moulds, vessels, &c. it is cast in be moist, it flies into numerous particles, like shot from a gun, with an incredible noise, and may destroy the persons near it. For this reason the *Swedish* miners are cautious of admitting any body to be present at their meltings, lest chancing to spit, sneeze, or the like, they bring instant destruction on them all.

(p) The dissolution of copper in the air shews itself by an *erugo*, or rust covering the metal; which when view'd with a microscope, appears as a cluster of crystals of different colours, according to the salt that produced them. Thus copper, suspended in the vinegar-houses, immediately contracts a rust, and grows green; and the same is effected by

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green, common and other salts; which being sprinkled over the most polish'd copper-plate, turn it rusty in a day's time. Nay, oils themselves dissolve copper; witness oil of olives, &c. but it must be added, they do this by means of a salt contain'd in them. Copper, dissolved by acids or fix'd alcalies, turns green; and by volatile alcalies, of a beautiful blue.

From this common reception of all menstrua, copper is called by the chemists *Venus*, that is, *meretrix publica*, a common prostitute. Other metals have their peculiar dissolvents, but this is dissolv'd by all.

The extreme divisibility of copper exceeds all imagination: Mr. Boyle making a solution of a single grain of the metal, in spirit of sal-ammoniac, found it would give a blue colour to 256806 times its own bulk of clear water; nay, a manifest tincture to above 385200; and a faint, yet discernible one, to above 530620 times its bulk*.

(q) Copper ore is found in divers places, both in *Europe*, *Asia*, and *America*; but in the greatest quantity in *Sweden*, *Hungary*, and *Germany*; where there are whole mountains of it.

Wherever copper is found, there is always vitriol; and that generally of all the three kinds; viz. green, blue, and white: with copper are likewise found the richest and brightest-colour'd gems, as emeralds, turquoises, and the like green and blue precious stones.

* See Boyle Abr. Vol. I. p. 408, 409.

green, blue, ruddy and white vitriol; also beautiful green and blue stones: so that no fossil metalline matter has such a variety of beautiful colours (r).

(r) The separating of copper from its ore is very difficult; to which difficulty is owing the great price which the metal bears. For 'tis found in such abundance, that were it not for this, it might be sold extremely cheap; but it adheres so strongly to the stony matter, that 'tis a wonder it should ever be separated at all.

Ercker says it must pass through fourteen furnaces before it be pure. So long as any of the stony substance adheres to it, it remains friable: but a portion of that is separable and cast off at every fusion: 'till, at length, after the fourteenth fusion, it is all extracted and the metal left red; and malleable.

ADDITIONS to the Article COPPER.

Its natural history.

It is sometimes found native and pure in the form of twigs, rods, branches, balls, or grains; but generally mix'd in gleans, pyrites, or ores. Some copper ores are yellow, violet, purple, green, blue, blackish, bright gold colour'd, &c. It is often accompanied with the ores of silver, iron, or lead; and commonly contains a large quantity of combustible common sulphur.

Copper ore is sometimes also found in form of a dust or powder; and sometimes procured from the water of certain springs containing vitriol. In the mines of *Hungary*, *Dr. Brown* observes, there are divers sorts of ore, but the chief difference is between the yellow and the black; the first whereof is pure copper ore: the black also contains a portion of silver*.

How separated from the ore.

The ore is differently treated according to the substances wherewith it is mixed. If it abounds with silver, 'tis first gently roasted, till a great part of the sulphur goes off in fume. At *Goslar*, in *Germany*, they first break the ore into pretty large lumps, then burn it in an open fire of wood and charcoal; after which they beat it smaller, and roast it twice again: and thus make it fit for the first furnace, where it is melted into a stony red matter, called copper-stone; which being again roasted and melted becomes black-copper, this they roast again, in order to free it from its sulphur; and now it is in a fit state to be treated for its silver; which they get out by adding four parts of lead to one of the black-copper, then melting them together in a strong fire, and casting the mass into moulds, where it hardens into blocks. These they carry to another furnace, and bury in charcoal; giving only a gentle heat, till the lead and silver melt and run away together, into the basin or receiver, leaving the copper blocks unmelted behind, which are thus honey-comb'd, and drain'd of their silver; but left capable of being brought

to malleable copper, by repeated fusions. In the *Hungarian* mines, *Dr. Brown* tells us, they sometimes burn the ore, and sometimes melt it; and this, sometimes by it self, and sometimes mixed with other minerals, and its own dross. He adds, that an hundred weight of ore will yield 20, 30, 40, nay 50 and 60 pound of metal†.

The purification of copper chiefly depends upon totally freeing it from its sulphur, which may be done, for the more curious uses, by melting it several times with fix'd alkali, nitre, or borax.

Its medicinal virtues.

'Tis of importance to a physician to be well acquainted with the nature and properties of copper; as it furnishes a great variety of remedies. It may be said that what *Paracelsus* and *Helmont* have advanced of an universal remedy, seems to hold of copper. Thus, *Butler's* famous stone, if there be any truth in the account, was a preparation of this metal: the celebrated remedy of *Van Helmont* was a sulphur of vitriol, fix'd by a long calcination and cohobation. *Mr. Boyle's Ens veneris* is a vitriol of copper made with sal-ammoniac. Copper is an excellent emetic, having this singular virtue, that it exerts its force as soon as ever 'tis taken; whereas other emetics lie long in the stomach before they operate. But a single grain of verdigrease immediately vomits; and hence, syrups, &c. which have stood all night in copper vessels occasion vomiting.

Copper has been swallowed crude without harm; and returned without dissolving in the body. But its preparations, given internally, sometimes prove so violent and hazardous, that few chuse to employ them where safer medicines may answer the end. They are most of them emetic, and disorder the body too much; so as to approach the nature of poisons, rather than that of remedies.

Its common uses.

Its uses in mixture are known. Thus with

† Ibid.

* *Phil. Trans.* No 59.

Of IRON.

Iron, its characters.
Weight.
Simplicity.

1. Iron is (1) distinguishable by its proper gravity (s).
- (2) Less simple than the preceding metals; as affording manifest indications of a crude sulphur, or combustible matter adhering to it, which frequently appears in live flames (t).
- (3) Pretty fix'd in the fire; yet so as to fume and sparkle, as it were, with combustible matter, and thus continually loses of its weight (u).
- (4) Ductile under the hammer, and may be drawn into wire, but not of an exceeding fineness; for then it cracks or snaps. It is also hard and sonorous (x).
- (5) Ignites long before it fuses; nor melts without a violent fire; and this the most slowly of all metals: when red-hot it will bear the contact of cold water, without danger to the by-standers (y).
- (6) It easily dissolves with any salt, growing ruddy therewith; readily lets

Diffolution.

tin it makes a bell-metal, and a good metal for microscopes, or reflecting telescopes. With calamine it makes brass, with zink prince's metal, with grape-husks it makes verdigrease, &c.

Hints for its alchemical history.

Exposed upon a tile to the focus of a burning glass it turns to a reddish calx, then melts into a deep red, and almost opaque glass; which is reducible to copper by being melted upon charcoal. It burns and gives a green flame in the fire, or a candle. Ground and distilled with sublimate, the copper remains behind with the salts, in form of a red inflammable rosin that burns green. Hence *quære*, whether it be not composed of an inflammable sulphur, and a red vitrifiable earth?

(s) *Vid.* the table, where it is shewn to be next in weight to copper.

(t) The abundance of sulphur in iron is apparent from the sparks it emits, when ignited, and beat under the smith's hammer; those sparks being owing to the sulphur of the iron: nor is there any thing like them seen in any other metal.

(u) It is very fixed, as to its metalline part, but not its sulphureous one. This latter is pretty easily volatilized, and consumed by fire; as appears from the sulphureous smell of iron, either ignited, or melted. If you expose iron to an intense fire, it grows warm, reddens, burns, turns of a flame colour, and at length emits sparks, and then runs. If it be now taken away, it will be found softer for the fusion: but if you continue it in the fire, it comes at last to yield a whitish fume; and thus loses a great part of its body, *viz.* its sulphur.

(x) It is the least ductile, the hardest, and

most brittle of all the metals. Yet by fusing it we can render it still harder, and more brittle, and scarce capable of being drawn, or extended at all: or, if it be only ignited, and then quenched in cold water, it grows harder, and loses much of its former ductility; and the more so, as the water is colder, and denser, and the extinction more sudden. This extraordinary brittleness of iron arises from the sulphur intermixed with it: and the greater quantity it contains, the more brittleness does it impart to the metal.

(y) It fuses with difficulty, and contrary to the nature of all other metals, the more it is ignited, the softer, and more ductile it becomes; being scarce flexible or malleable at all till after ignition.

Add, that when in a state of ignition, both its weight and dimensions are greater than when cold. M. Muschenbroeck, counterpoising a prism of iron of three pound weight in a nice pair of scales, which would even turn with $\frac{1}{20}$ of a grain; and afterwards heating the prism red-hot, found that it still weighed exactly three pound: whence he concludes, that it had gained in weight from the fire. For the experiment being made in open air; and heat being always found to dilate iron; 'tis evident the specific gravity of the metal must have been diminished by such dilatation: which must have been perceived by the scales, unless some new weight had been added to it from another quarter*. This accession of weight may arise from the fiery particles fixing therein: and if, when ignited, it be prevented from extending itself, it bursts; and either breaks, or throws off any body that restrained it.

* *De Mater. Subt.*

- go its solvent again, and turns into a ferruginous *Scoria*. Hence it is extremely inclined to rust (z).
- Rust.* (7) It is the most easily destroy'd of all metals: with lead and antimony it immediately turns to *Scoria* (a).
- Destructible.* (8) It is attracted by and attracts the load-stone (b).
- Magnetism.* (9) It has great medicinal virtues, being nearer allied to the human body than any of the other metals; so as to be almost wholly dissolvable therein (c).
- Salubrity.* 2. Iron seems to be produced in all countries. It is found in unctuous marly earths; which when burnt in the fire, discover their metal by the redness of the colour. It is also found in a stony ore, where it shews it self by a rusty colour, or, if it be rich, by a pale bluish one, and sometimes also by its magnetic power. It is likewise manifestly known to be in the green, fossil

Where found.
In what form ore.

(z) It is easily dissolvable in salts, dew, air, &c. By the action of any of these it contracts a rust; which is nothing but the flowers of iron; or iron dissolved, and relinquished by its dissolvent: for iron being examined with a microscope, when first it becomes rusty, shew'd its surface cover'd over with a number of pellucid, vitriolic *lamellæ*, or gleebs; which being afterwards dried, by the fluid menstruum's evaporating, become a ruddy calx. Hence an oily matter perfectly destitute of all salt, or acidity, being smear'd over iron, hinders its rusting; by preventing the access of the air, the salts floating where-in would prey upon it.

And hence the method used by artificers to preserve iron bright; *viz.* by oil of olives boiled with a little litharge, or ceruss, which absorbs the acidity of the oil; or they only boil the oil to a thickness, and so exhale the acid, before they use it.

In effect, all salts, unless we except the alkaline, have a power of dissolving iron. And hence that elegant experiment of taking a large plate of iron, and applying to it, in one place, a drop of water; in another a drop of vinegar; in another spirit of vitriol, &c. for all these several menstrua will bring a different rust on the metal, according to the nature of the menstruum employed.

(a) It neither resists the force of lead, nor antimony; but being fused with them, readily dissipates in fume, vitrifies, or turns to *Scoria*.

(b) But it must be remember'd that iron itself may be brought to attract iron; or that it may become a magnet with respect to it self. Dr. Gilbert observ'd long ago, and Mr. Boyle confirms the observation, that iron rods, as the bars of windows, by standing a long time in a perpendicular position, will grow magnetical: so that the bottom of the bar will at-

tract the Southern end of an animated needle, and repel the Northern; but the upper end attract the Northern, and repel the Southern.

Mr. Boyle has even found, that a bar of iron, without standing long in an erect posture, by merely holding it perpendicularly, will acquire the same virtue; but then the virtue will be transient; so that if you do but invert the bar, its poles will be changed.

The same author observes further, that the same virtue which a bar of iron acquires in a long course of time, merely by its position, may be soon imparted to it by means of fire. And hence we find, that the same experiment holds in tongs, and other iron utensils, which have been set to cool, leaning against the wall.

And hence, probably, the story current among the Italian naturalists, *viz.* that a large iron bar, supporting a cross of an hundred pound weight, on the top of a church of *Arimini*, was transmuted into an actual load-stone; a piece of which was preserved, among other rarities, in the repository of *Aldrovandus*.

Mr. Boyle adds, that having brought a large piece of English oker to a proper shape, and then made it red-hot, and let it cool again in an erect posture, it discovered a magnetical virtue; and would attract one end of a needle, and repel the other*. But whether this last case be not accountable for from the ferruginous matter wherewith that mineral is known to abound, even beyond some iron-ores, contained in the oker, will admit of a doubt.

(c) Iron is one of the noblest remedies in all medicine; perhaps of more efficacy, in chronical cases, than all animal and vegetable matters put together. 'Tis greatly strengthening and aperitive, astringent or styptic, as 'tis differently prepared.

* See Boyle Abr. Vol. I. p. 499.

fossil vitriol (*d*). But to reduce the ores to pure iron, requires an intense fire; with certain proper additions, and previous roasting (*e*).

(*d*) Iron is found in most parts of the globe; nay, even in all sorts of matter: particularly, all the parts of animals, both solids and fluids; as milk, urine, blood, fat, bones, flesh, &c. Out of any of these iron is procured, by calcining them, and then drawing a load-stone, or the edge of a knife touch'd with a load-stone, lightly over the calx, or ashes: for the iron particles are by this means drawn out of the ashes, and adhere to the knife.

Again, earths calcined, afford iron; as we see in clays, and potter's-earths; it being the iron alone that gives them their reddish colour, when burnt, or baked. The same is obvious of bricks, tiles, &c. which are made of a bluish, livid clay, and only become red in virtue of the iron particles mixed with them.

Dr. Lister imagines he discovered that iron is the basis of the stone in the bladder, and kidneys; and consequently, that the more we eat of vegetable and animal substances containing such iron, or the more chalybeates, or iron medicines we take, the more matter is supplied for the generation of that distemper. The foundation of this doctrine is that above-mentioned of iron extracted out of the calx of human urine, or milk, or blood, or bones, or the stones themselves taken from animals. But tho' thus much be allowed, still it may be doubted whether it is iron that generates the calculus. For when iron has contracted a rust, it is scarce attracted by the load-stone at all: so that it is a little unsafe to argue thus: "all vegetable and animal substances afford a calx which is attracted by the load-stone; consequently the iron we take furnishes the matter of the stone:" since iron itself, if changed by a salt, or acid, or even by heat, does not fly to the magnet. That excellent author, therefore, has carried the point a little too far: and accordingly, all he has wrote on this principle, about spaw-waters, and chalybeate medicines, must be looked on as very precarious and hypothetical.

The running of iron from its ore.

Iron is rarely found in its own form; but

most commonly in black, or brown glèbes; from which it is scarce to be separated by fire alone; without some addition to absorb the sulphureous part. By this means the metal is brought to run fluid, and received in moulds of different forms, according to the works it is intended for.

Natural history of iron.

(*e*) Iron mines are common in most countries of Europe; Norway, Poland, Germany, France, England, &c. abound with them: only America which is so plentiful in gold and silver mines, has none of iron: and accordingly, the natives prefer a metal of so much use, infinitely beyond their own treasures. In some mines in Silesia, M. Stahl observes, they find grains of iron, already malleable. Mr. Boyle adds, that one of the best sorts of Swedish iron is found in form of a mud, at the bottom of lakes, and other stagnant waters.

Its common glebe, or marcasite, bears a near resemblance to the load-stone; as in effect, that stone always yields true iron. Sometimes, it is in pieces as big as the fist; and sometimes only in a sand. Again, in some places, it is on the surface of the earth, or scarce an inch or two deep; but 'tis more common to have it at a depth of four, five, or six feet.

The forest of Dean, in Gloucestershire, is particularly rich in iron-ore; which it yields of divers colours, weight, &c. The best is that of a bluish colour, heavy, and full of shining specks, like grains of silver: but this, tho' it yields the greatest quantity of iron; yet, being melted alone, the metal is too short and brittle. To remedy this, they mix it with the cinder, or remains of old ore melted down long ago; which gives it that excellent temper and toughness, for which this iron is so much preferred to any other.

In the iron-works, at Milbrop, in Lancashire, they use turf along with the charcoal, which makes the iron better than the coal alone. Beside, to the calx thus produced, they add about $\frac{1}{10}$ of the quantity of lime-stone unburnt, to make it melt more freely, and cast the cinder, which they take off before they let the metal run $\dagger$.

ADDITIONS to the Article IRON.

Its natural history.

Iron, being the most useful, as well as the most common of all metals, deserves to have its history carefully traced, and its nature

thoroughly enquired into. In some few mines it is now and then found native and pure, either granulated, or in small twigs, or lumps. Its ore is found of very different forms and colours.

* Phil. Trans. N^o. 137.

† Phil. Trans. N^o. 199.

lours; sometimes it appears as a ponderous, dark, yellow, or reddish stone; sometimes like a hone, or a whetstone; sometimes as oker, marcasites, ruddle, or red sand. These different ores are also different in their natures, with respect to the iron they afford by the same treatment. Thus there is a peculiar German ore, smelted in Holland, which affords an almost malleable iron, at the first running, and thus makes plates that will cut or file with great ease, to very great utility. If this property could be found in other iron ores, or could by art be cheaply communicated to them, it would prove an universal benefit. We have scarce any iron in England fit to make good steel of; the German iron above mentioned makes it excellently. This being the best kind of iron ore hitherto known, we shall find, by tracing the subject, that there are numerous intermediate ores, till at length we descend to such as will afford only a rotten worthless metal, not deserving the name. Again, some iron-ore yields this metal easily, and without any addition; others with difficulty, and require additions to lay hold of their superabundant sulphur. For this purpose they use lime-stone, quick-lime, marl, stones, slag, or other cheap materials, that will fix and detain sulphur. The toughest, or most malleable iron is the best; that which is brittle or rotten being of the least value, or use: tho' perhaps this difference may not proceed from any real difference in the proper metallic part, but be wholly owing to the earthy, gross, vitriolic, and sulphureous matters adhering to it, or intimately combin'd therewith; whence proper experiments should be made to try whether such matters could not be advantageously separated from the metal. Many particulars tending to this end, may be learnt by conversing with skilful workers in iron, and are, perhaps, such as few philosophers would dream of. But to treat this subject properly would require a volume.

How separated from the ore.

The common ways of separating iron from its ore are already explain'd; tho' perhaps they might be greatly improv'd, by using suitable additions, and mixtures of earthy, alkaline substances; and a peculiarly adapted fuel. The strongest fire, in a considerable body, and actual contact of a large quantity of the ore with a vegetable fuel, are the common requisites to the making of good iron; the furnaces being built in such a manner as that the ore shall burn as fuel. Perhaps no iron is procurable even from the best sort of ore, in a closely-cover'd crucible, or melting-

pot. A mixture of ore will often yield metal, when the ores separately could not be work'd to advantage. The iron smelting-furnaces are so contriv'd that the metal, when it runs, may flow into a proper receiver at the bottom: where it may be let out at a tap-hole, so as to run into a bed of sand, as into a mould, where it receives the form of what they call pigs, or sows. But sand renders the surface of the metal unequal, and perhaps, affects its more internal parts, either on account of the air, moisture, &c. contained in the sand: whence it might be adviseable to contrive a better bed for it, of some proper earth, that should neither disturb its external nor internal parts; whence the metal might, probably, prove softer, and more equable; or require less labour to make it malleable.

How made malleable.

The pig, or sow-metal is not malleable, but render'd so by being beat hot, which seems to squeeze out of it a kind of drossy matter less metallic than what now remains wedged close together, and laid even by the force of repeated blows. The common method wherein this is done, will be better learnt from seeing the work, than by reading any description of it.

History of steel.

The business of steel remains somewhat obscure: the naturalists from Aristotle to our time, speak of the making it in terms which leave a man greatly to seek for the precise method thereof. It seems the artists have had the address to elude their enquiries; and still keep somewhat of the mystery to themselves.

Aristotle says, that steel is only iron defecated, and made pure, by repeated fusions; for the impure parts, or Scoriae, he observes, subside, and are purged off by the bottom*. And the like account is given by several later writers. But Dr. Lister shews they are all mistaken: iron, of it self, he notes, how oft soever purged, and refined, will never become steel, without other addition†.

The chemists, with the generality of late writers, as Dr. Plott, &c. will have steel made by keeping the iron ignited some time, amidst the fire and fume of bullocks horns and hoofs, and charcoal made of beech, or willow; and then plunging it in cold astringent decoctions. But these additions appear to be no better than a blind; they are necessarily required for case-hardening of iron, which may have led authors into the notion; but don't contribute any thing to the converting it into steel.

Kircher and Agricola describe the method of making steel, as practis'd in the island of Iloa, a place anciently famous for this metal:

"The

* Meteor. l. 4. c. 6.

† Philos. Transf. N° 203.

"the iron is first heated red-hot, then cut in small pieces, and thus mixed with a sort of stone which promotes the fusion: then, a crucible is set in a smith's forge, and filled with charcoal. When the vessel is red-hot, they put in by little and little, the mixture of iron and stone. As soon as 'tis melted, they thrust three or four pieces of iron into the middle thereof, and keep them boiling therein, with a strong fire, five or six hours; observing from time to time, to stir the melted metal, that the pieces of iron may imbibe the smaller, subtiler particles thereof, and have their own grosser particles attenuated thereby. Lastly, taking out the pieces, they forge them, and draw them into bars; and thus, hot as they are, plunge them into cold water: taking them out from hence, they are found steel; tho' not so perfect, but that they frequently make them undergo the process a second time; first casting some fresh matter into the crucible *."

Iron, how converted into steel, in the large way.

The making of iron into steel appears to be the work of the fire; whilst the metal is defended from the external air. The manner is this. They take rods of fine soft iron, about an inch broad, and lay them upon one another in a furnace, built after the manner of a chest; with care to strew charcoal-dust between them so as to keep them from touching; when the furnace is filled, they cover it close on all sides, using a proper luting for the purpose, and keep up the fire, as in a reverberatory furnace, so as to make the bars red-hot without melting; and in this state they are kept, from the external air, seven or eight hours; then, suffering the fire to go out of it self, and the furnace to cool, they open it, and find the bars changed into steel. Some use street-mud along with charcoal-dust; the mud being first baked, and powdered. The operation is known to be perfect, if upon snapping a bar, it shines, or looks quite through full of bright spangles, which the workmen call the grain. If it does not appear thus, quite through, the operation is to be repeated. There are several curious particulars to be observ'd in this operation, relating to the difference betwixt iron and steel, &c. which we cannot now consider.—It is found that the purest and softest iron makes the best steel.

The medicinal virtues of iron.

The internal medical virtues of iron were not unknown to the ancients. *Dioscorides* attributes an astringent virtue to it, and recom-

mends it in internal hæmorrhages. It is allowed an excellent remedy in many disorders; but requires a prudent management. It may safely and advantageously be taken crude, or in filings, provided the dose be not so large as to load the stomach. It is remarkable that the virtues of iron, and its various preparations correspond to its taste, which is styptic, so as to contract the fibres of the tongue, and the whole mouth; thus occasioning a large discharge of the saliva. It seems to act in the body, chiefly by means of its vitriolic salt. 'Tis allowed to produce effects quite contrary in name, so as to constringe and evacuate; to purge and bind; to promote the menses, and check them, &c. all which is easily understood from knowing its nature, and the manner of its acting upon the solids and fluids of the body, by means chiefly of its stypticity or vitriolic quality. Whether the best ways of preparing it for internal use are known, is uncertain. Some ways of preparing it seem rather to spoil it; as those by calcination, or reverberation to make a crocus. The softest cleanest iron seems best for medicinal use; but perhaps some of its soft native ores, if properly purified and extracted without much fire, are better in physic than the metal.

Hints for its alchemical history.

Iron exposed upon a tile to the focus of a burning-glass, melts, fumes, and vitrifies; but if laid on charcoal, only melts, and presently flies off in sparks. But the vitrified substance left upon the tile, being transferred upon a piece of charcoal, and again exposed, recovers its metalline form. All the experiments hitherto known to have been made upon iron, being considered, it should seem as if it consisted largely of a bituminous matter, or sulphur, a vitriolic salt, and a vitrifiable earth. Hence may appear the reason why iron is found upon burning plants to ashes; its earth uniting with any inflammable substance in the fire, so as to generate iron.

What relation has iron to brimstone and antimony?

What are the relations betwixt iron and copper?

Is there not a small proportion of copper in iron?

What relation has iron to the poisonous part of cobalt?

What is the physical reason why good malleable iron has not hitherto been made with pit-coal?

Does not iron contain an actual burning matter, or bitumen, in the nature of fewel? and is not this bitumen communicable to other metals, minerals, &c.?

O

What

* *Agric. de re metal.* lib. 9.

OF TIN.

Tin, its characters.

Levity.

Composition.

Volatility.

Ductility.

Fusibility.

Dissolution.

Endures lead, &c.

Affinity to silver.

1. Tin is (1) the lightest of all metals.

(2) The least simple of metals; being brought by a small degree of fire to emit sulphurous fumes, which are easily separable from the metalline part, and almost combustible (f).

(3) Hence less fixed in the fire than any of the other metals.

(4) It is soft, flexible, malleable, and may be drawn into wire, but not so well as the former; neither is it very sonorous, or elastic (g).

(5) It melts more easily than any of the other metals, long before it ignites, and with a degree of heat little greater than that of boiling water: it readily hardens again in the cold.

(6) When crude, or accompanied with its adhering sulphur, it dissolves only in *aqua regia*; but when purified of its sulphur, by calcination, it dissolves even in vinegar, and requires only a small proportion of that solvent (b).

(7) It so far endures lead and antimony in the refiners test, as hardly to be separable therefrom, without the assistance of copper.

(8) In many of its properties it approaches to silver (i).

2. It

What are the several ways of making artificial iron, and upon what principle do they depend?

(f) Of all metals it is the least fix'd in the fire, and affords the greatest quantity of sulphurous fumes; consequently loses most weight in the fire. The fume thus emitted seems to be the sulphur of the metal; which is pernicious to the lungs; as those who are employed in melting tin find to their cost; it usually giving them a pale, ghastly complexion, and throwing them into a phthisis.

(g) Tho' it be very little sonorous, or the least of any metal, except lead; yet when mixed with other bodies it may augment their sound; as in the composition of bell-metal: and so tho' it be but little elastic in itself; yet when mixed with other elastic bodies, it may increase their elasticity.

A body, Mr. Boyle observes, by being associated with another, may have new properties and uses, and some of them quite different from what it had alone; thus, two or more materials being conjoined, may be qualified into a third, by virtue of fresh properties thence accruing to the composition. As tin is flexible and yields but a dead sound, who would dream that one considerable use of it should be to make a less yielding and better sounding metal, more strong and sonorous? Yet bell-metal is principally composed of tin and copper †.

(b) Acids do not dissolve it without great difficulty, especially the more powerful ones.

The reason hereof is apparently its abounding with sulphur; which acids do not touch. Add, that it dissolves in *aqua regia*, scarcely in *aqua fortis*; which is a circumstance remarkable enough, considering the near alliance it has with silver. Again, the weaker the acid *menstruum* is, the sooner and the easier it works its end; and the stronger, the more slowly: thus, four apples and other unripe fruits, being boiled in tin-vessels, will grow sweetish; but the strongest acids, boiled in the same vessels make no solution at all. But tin, freed by calcination of its sulphur, dissolves in all acids; and is reducible thereby into vitriolic crystals. This solution is little practised by reason of the difficulty attending it; for the tin must be first thoroughly calcined, before a solution is attempted; and the calcination requires a continual fire for three days; after which the calx is dissoluble in common vinegar.

(i) If the sulphur could be perfectly purged out of tin, 'tis likely it might approach to silver; for as it is, the two metals have several properties in common. Thus, when dissolved in strong acids, tin grows bitter, as well as silver; and when it is fused along with silver, it adheres so obstinately thereto, that there is scarce any separating them. Add, that under such circumstances it resists lead, almost as much as the silver does. And hence many account it an imperfect species of that metal.

It may admit of some doubt, whether tin bears

* See the French memoirs and Stahl.

† See Boyle Abr. Vol. I. p. 147.

2. It is found in a very heavy ore; tho' itself be light; usually in a brown glebe, inclining to yellow, or in a black smooth shining one, which is the richest kind; sometimes like iron-stone, and sometimes it is also found in a heavy porous stone (k).

Found in what form.

The metal is procured by roasting, grinding, washing, then melting the ore, and thus separating the *Scoria* from it (l).

O 2

It

bears these resemblances to silver, in virtue of its being tin, or only in virtue of the particles of silver mixed therewith. 'Tis certain more of these resemblances, and those in a greater degree, are found in some species of tin than others. Mr. Boyle mentions a gentleman, who having procured a good quantity of the nobler metals from some *tin-ore* long digested in lixiviate liquors, desired Mr. Boyle to purchase him a large quantity thereof; in full expectation of raising an estate. But, says Mr. Boyle, after his first stock of ore was spent; the next that he procured, tho' managed with the same care as the former, proved wholly unprofitable.

The same author relates, that having dissolved some *black-tin*, (for so the workmen call that which is pure and unwrought) in a particular *menstruum*, which kept it suspended: and having afterwards evaporated the solution, and set it to shoot; he found, to his surprise, that the crystals it afforded were not all like its own kind of vitriol, but broad, flat, and thin like those of silver: upon examining them farther by the tongue, they had nothing of the taste of calx of tin made in spirit of vinegar; but that excessive bitterness we meet with in the crystals of silver made by *aqua fortis*. He adds this further resemblance betwixt the salts of these two metals, that both of them presently tinged the nails and skin with a black that would not easily wash off; whence he might have suspected that the *menstruum* had exalted the metal into an affinity with silver, had he not afterwards prosecuted the same trial with the same *menstruum*, and another parcel of *black-tin*; and found, that tho' this metal was bought at the same place, and very soon after the other, yet the former success was owing to his having lighted of a lump of tin that was of a peculiar nature †.

Some authors speak much of the analogy between tin and lead; and will have tin to be lead, only under a less degree of coction: but if there be some circumstances wherein they correspond, they differ in others. Lead, for instance, is easily reduced to a calx; and tin more easily still: but the calx of lead readily melts, and runs into a brownish glass; whereas tin does not vitrify without much diffi-

culty. Tin and lead readily mix and unite with each other by a gentle fire; but if the heat be intense, there arises a colluctation between them; the effect of which is that both fall into a calx; and that the lead becomes exceeding difficult, afterwards, to fuse and vitrify. Add, that tin is easy to be revived; but lead, not without difficulty: nor is the restoration any thing complete; or the new body in all respects like the old one.

(k) Tin-ore is principally found in *Cornwall*, and *Devonshire*, from whence all the rest of *Europe* is supplied with this metal. 'Tis so much the peculiar produce of this country, that *Cambden* supposes it to have given the denomination *Britain* to the island.

History of tin-ore.

(l) The stones from which tin is wrought, Dr. Merret tells us, are usually found betwixt two walls of iron-coloured rocks, of little or no affinity with the tin; in a vein betwixt four and eighteen inches broad: tho' instead of stones, they sometimes also find it mixed with a small gravelly earth, generally of a red colour, but sometimes white. From this earth, the tin is easily separated by bare washing; which is called *Prian tin*, and is scarce half the value of the former.

In the tin-ore is frequently found a hard glittering sulphurous substance, called *Mundic*, or *Maxy*, which is commonly supposed to feed the metal; yet where the *Mundic* abounds, they rarely find much tin. This *Mundic* is to be carefully separated; for if there be the least of it left, in melting the tin, it makes it brittle and cruddy, and diminishes much of its ductility.

There also occurs a sort of spar, of a shining whitish substance, soft and fattish at first, but soon after it becomes somewhat harder: it seldom grows, but only sticks to the metal. Some of the miners account this the mother, or nourisher of the metal. The best ore is that in sparks, and next to this, that which has bright spar in it.

The ore being dug, they break the greater stones, and thus carry it to the stamping or knocking-mill, where it is pounded with large lifters headed with iron, 30 or 40 pound a-piece;

* See Boyle Abr. Vol. I. p. 156.

† See Boyle Abr. Vol. I. p. 156, 157.

Plentifully
found in Bri-
tain.

It is found plentifully in *Great Britain*, and of the best kind; inasmuch that *Bochart* hence derives the name *Britannia*, which he supposes formed from the *Syriac*, *Barat Anac*, that is, field of tin. From this history of metals we deduce the following corollaries.

COROL-

a-piece; and thus reduced into a small sand, to be washed out by a stream of water, discharged into it from a cock, thro' a brass grate into a *Launder*, or trench dug in the floor; out of which the water escapes, carrying with it the parts not metalline, which they call the *Causalty*, and leaving the other at bottom.

To clear away the *Mundic*, they dry, or burn the ore, thus separated, in a kiln, upon iron plates; keeping the matter constantly stirring, that all the *mundic* may by degrees get uppermost, and so be burnt away; which they discover by the flames growing yellow,

and the stench diminishing. Then they proceed to grind it again, very fine, in a *crazing-mill*: after which they wash it; then dry it a little; and at last, carry it, thus prepar'd, to the furnace, which they call a *blowing-house*; and there melt and cast it.

When it runs out of the furnace, there swims on it a dross or scum, like that of iron; which being melted down with fresh ore, runs into metal.

The *Causalty* they throw in heaps upon banks, which, in fix or seven years, they fetch over again*.

ADDITIONS to the Article TIN.

The ore of tin is commonly a black, ponderous, stony substance; appearing like black stones: but some tin-stones are yellow, and others white. Some are brittle, and others extremely hard; so as to require being broke before calcination.

Various matters are found mixed with tin-ore, but particularly *Mundic*, called the mother of tin: being of the arsenical tribe; and when exposed to the fire, chiefly going off in fume. It is also frequently mixed with an irony substance, that makes it very difficult to melt. 'Tis very remarkable that some tin-ore is specifically heavier than the metal it yields.

How separated from its ore.

In *Cornwall*, the ore is first separated from the uselefs barren earth, or stone, then roasted, beat and washed, to leave only the more metallic part behind; which is afterwards ground and wash'd again; when being dried 'tis committed to the furnace, mix'd with charcoal, and melted by a strong fire, blown with bellows. The melted tin thus runs to the bottom of the furnace; where a tap-hole being open'd, it is drawn off into moulds, that give it the form of blocks.

Its medicinal virtues.

Tin is seldom used internally; tho' its virtues are highly extoll'd by some; but we fear upon no just grounds; and particularly in diseases of the head, the lungs and uterus, the falling-sickness, and the bite of a mad-dog. It has been taken in crude filings to the quantity of twenty grains, or more, every day, for some time, without harm.

Its uses.

Besides the utensils and vessels made of this metal, it serves to preserve iron and copper; for being extremely easy to melt, and by means of any unctuous matter, adhering closely to them; hence has proceeded the art of tinning. It likewise serves in solders. Amalgamated with mercury, it serves for the foiling of looking-glasses, &c. By calcination it makes putty; which is of great use in the polishing of gems, and the making of enamels. It is a principal ingredient in pewter, as well as bell-metal. It mixes well with zink and regulus of antimony, and thus becomes whiter and harder; but too much regulus makes it brittle.

Hints for its alchemical history.

Being exposed on a tile to the focus of a burning glass, it sends off a thick gross fume in great plenty; leaving a fine light white cake behind; which being continued longer in the focus turns to thin transparent glassy strings; that melt no more without the addition of an unctuous substance, or charcoal; whereby it returns to tin. It deslagrates with nitre; hence, perhaps, this metal consists of a copious sulphur, or particular bitumen, and a fine vitrifiable earth; mix'd, on account of its poisonous quality, with a minute proportion of an arsenical salt.

Why does it render other metals brittle, even in the form of fume? and why is it so difficult to separate it from them?

What would long digestion do, towards ripening it into silver? and what previous operations would it require?

APPENDIX

* *Phil. Trans.* N°. 69. p. 2096. and N°. 138. p. 948.

APPENDIX TO THE HISTORY OF METALS.

1. We have now gone thro' the first class of fossils, *viz. metals*; and what we have here done may serve as a specimen in what manner physical things are to be treated: not by supposing any previous hypothesis, and deducing their nature therefrom; but laying down their several apparent properties. But this part will be reckoned incomplete without the alchemical doctrine of metals.

2. That which distinguishes metals from all other bodies, as well as from each other, is their *degree of weight*; for every metal is found to have its peculiar weight, which depends, as *Helmont*, and the chemists express it, on the *atomic homogeneity* of the parts.

Now, the latter philosophers have proved, that all corporeal magnitude has just so much reality as weight: and therefore if you have found the weight of any metal, you have at the same time found its corporeity. Sir *Isaac Newton*, in treating of gravity, and *M. Huygens* of the pendulum, shew that weight and quantity of matter are correspondent.

3. Metals appear to be simple, and yet are really compounds; their component principles, according to the ancients, are *sulphur*, and *mercury*; to which some of the moderns have added *salt*; tho' perhaps salt is no proper constituent part of metals; but rather something external adhering to them; and which makes no part of their metalline composition.

"In the analysis of metals, we meet with mercury, a sulphurous matter, an earthy matter, and in some a saline matter *." But this is chiefly to be understood of the imperfect metals; or of perfect ones not in their utmost purity; tho' the burning-glass we have already observed, separates a vitrifiable earth, even from the most perfect of all.

All metals then consist of two kinds of parts, or principles, *viz. mercury*, as the basis, or matter; and *sulphur*, as the binder or cement: the first, the substratum, or metalline matter; the second, that which renders it fix'd and malleable.

This *mercury* is supposed to be the same with quicksilver, only more pure and clear of any of those heterogeneous matters, wherewith the common quicksilver is mixed: as to the *sulphur*, it is not the vulgar fossil sulphur, but a peculiar sort of matter, specifically denominated *sulphur of metals*, and said by some of our latest and best chemists, particularly *M. Homberg*, to be light, or fire. This being united with the mercury, fixes it; and accord-

ing to the different degrees of union and coherence therewith, produces different metals.

This doctrine of the composition of metals, is confirmed by an experiment of the same *M. Homberg*, who after having retained mercury a long time in a moderate fire, thence obtained gold out of it which was not in the mercury before. From whence he infers, that gold consists of a sulphurous or igneous part; and a heavy, mercurial part fixed thereby: and that by only taking away the sulphurous, or fiery part of the gold, it is reduced to running mercury.

There are two ways of effecting this, *viz.* either by the revivifying salts of vegetables, or by mercury. That by mercury, *M. Homberg* assures us, is easy; since mercury being purged of all heterogeneous matters, becomes a menstruum that dissolves gold, by attracting, and melting the sulphur which fix'd the parts together. The like is done by those salts, which, from their effect, are denominated *revivifying*, *viz.* by penetrating the metals, and absorbing the fixed parts; whence they resuscitate metals into their principles.

If it be ask'd why gold, if it only consist of the above mentioned principles, should be heavier than mercury? the answer is, that the particles of fire, or light, which *Mr. Boyle*, and *M. Homberg* demonstrate to be heavy, coming to insinuate themselves into the pores of the mercury, and their fixing; increase its specific gravity.

Silver, according to the same *M. Homberg*, differs from gold in nothing but this, that the globules of its mercury are not so much penetrated, nor so thoroughly saturated with the sulphurous principle or fire; a less quantity of which being lodg'd in the pores of silver, than of gold, leaves it short in point of gravity, &c. and does not discolour it.

Accordingly, proceeding on this supposition, he found that he could produce gold, by introducing a large quantity of fire, or of the rays of light into silver. And hence he thinks it appears, that gold should be longer in forming than silver; and that all gold was first silver †.

4. All metals, 'tis said, must first be mercury, before they become gold or silver; and that the thing superadded to the common mercury, whereby it is prevented from becoming gold, is a volatile body; which, when heated, becomes corrosive, and emits fumes. This doctrine has been sufficiently laugh'd at, and

* *Homberg. Mem. de l'Acad. an. 1702.*

† *Mem. de l'Acad. an. 1709.*

and exploded by many philosophers, ignorant of the nature of metals.

In effect, what is here advanc'd seems the result of numerous experiments; nor does it appear, in any respect, inconsistent with reason: it must be admitted therefore, that mercury may be the matter of all metals; that as this is more or less pure, the metal is more or less ponderous; that there is no proof of matter so clear and strong, as what is deriv'd from weight; and that the specific nature of a metal is known thereby.

Hence the more knowing among the alchemists maintain, that, "if you would convert, for instance, a piece of tin into gold, you must first carry it thro' all the intermediate weights of the other metals, that is, it must first be the weight of iron, then of copper, then silver, then mercury, and at last gold."

"On this principle, whoever would make gold out of any other foreign matter, must remember; that the more his matter comes short of mercury in weight, &c. the less gold it will make; that if quicksilver could be raised to the weight of gold, it would be gold; that the matter which coagulates, or fixes this mercury into gold, &c. is subtle; and as quicksilver held over the fumes of lead, is readily fix'd, it appears that a very little fixing matter suffices; that if mercury, coagulated by sulphur, have any impurities therein, it becomes lighter, and less perfect than quicksilver; that nature in some cases is able to make gold, but not in others; and where she is unable to do this, there arises a less noble metal; and that if the sulphur be not strictly homogeneous, there will arise a still more imperfect metal."

5. If this doctrine be true, metals appear transmutable into one another. For if mer-

cury be the common matter of all metals; and if all the difference lie in the fixing matter, which, as 'tis more or less subtle and pure, constitutes this or that metal; 'tis not improbable they should be converted, by a purer fixing sulphur's taking place of a corrosive one, into a more perfect metal.

6. The purest metals are said to result from the purest mercury, join'd with the subtilest sulphur; hence the mercury of gold is heavier than the common mercury, which has always some impure part that is lighter than gold: and could that be taken away, and the fixing matter added, it would become gold.

7. The imperfect metals are said to consist of impure mercury, and imperfect sulphur; each containing some other heterogeneous matter in it. They farther assert, that nature sublimates mercury in the earth, by heat; which sublimation is repeated again and again, till every thing impure and heterogeneous be carried off, and what is pure left fix'd behind. This is the substance of the doctrine of the alchemists, so much exclaim'd against by other philosophers.

We have added what relates to the art of *transmuting*; that such as have the curiosity to make any experiments in this kind, may have some laws, marks, or aims, whereby they may securely direct themselves; and that such as might be in danger of being imposed on by fraudulent alchemists, may be furnished with means to discover the deceit.

This doctrine of transmutation may be of service to the beginners in chemistry; who, by a strange fatality, have an almost universal itch after the philosopher's stone, and the making of gold. Instances of vain people, reduced from plentiful fortunes to the lowest beggary, by their own conceits, or the empty pretensions of designing alchemists, fall under most people's observation.

COROL.

COROLLARIES drawn from the preceding History of METALS.

Corollaries on the constitution of metals. Weight the interior of metals.

1. That metals differ absolutely from all other natural or artificial bodies, hitherto discovered; since the lightest metal is more than double the weight of the heaviest non-metalline body (*m*).

2. They therefore are greatly mistaken, who expect by any conversion of substance to make metals out of bodies non-metalline; since condensation is the most difficult of all operations; and weight being the index of corporeal quantity, it requires something like a creative power to increase it (*n*).

Difficulty of making metals.

3. True metals do not discover the intimate affinity of their matter, by any thing more evidently than by their resemblance in point of weight.

Affinity of metals where- in.

4. Nothing therefore resembles gold more nearly than quicksilver; with regard to the matter in both. For the other principle, which gives each of them their particular form, we do not here inquire into it; tho' it should hence appear to be vastly different.

5. The other properties of metals, as fixity, colour, malleability and simplicity, may probably be produced, and changed with more ease than their weight.

Properties, which easiest chang'd.

6. Gold therefore consists of a most pure, simple matter, like mercury, fixed by another pure, simple, subtile principle, diffused thro' its minutest parts, and intimately uniting them to one another, and to it self. This the chemists mean when they say it consists of mercury and sulphur.

Gold, of what composed.

7. The other metals consist of the same principles, but together therewith have another lighter matter intermixed, which is different in the different metals, and is called earth. Consequently these are composed of three matters; to which in some may be added crude sulphur.

Impurer metals, of what composed.

8. The different metals therefore are resolvable into different elements, both in respect of nature, and number.

Elements of metals.

9. This resolution may be effected by means of mercury, regenerating salts, or fire; but differently according to the different metals (*o*).

Analysis of them.

10. It is a mistake therefore to say, that metals may be easily converted into one another; excepting with regard to the mercurial parts, and by first utterly destroying their form; and consequently the quantity of gold procured from any other metal, by transmutation, can only be in proportion to the quantity of mercury it before contained (*p*).

Transmutation of metals.

II.

(*m*) And yet some marcasites are as ponderous as some ores, and some tin-ore more ponderous than the metal it yields.

(*n*) The instances where this happens, or seems to happen, upon mixture or otherwise, should however be carefully collected and considered; as in the mixture of oil of vitriol and water; copper and tin, &c.†. It may be of pernicious consequence in natural philosophy, to draw conclusions not fully supported by the premises; and a very unsafe way to draw arguments against possibilities

from our ignorance of facts and experiments.

(*o*) Perhaps the shortest way is that by means of the burning lens; in the focus whereof, if a metal be exposed, what evaporates from it in fume might be catch'd in water or other fluids, to see if the fume would thus condense into mercury †.

(*p*) The alchemists pretend by their operations to heighten the virtue of the mercurial matter; or bring it to such a degree of subtilty and activity, as is no where found in nature, without the assistance of art.

† See Dr. Hook's posthumous works. ‡ See the French Memoirs, Mr. Boyle, Becher, and Stahl.

No new metals.

11. Nor does it appear that any besides the six above mentioned metals can be procured by art; how confidently soever *Van Helmont* may have asserted this of mercury fixed by the *Alkabeft*.

Preservative from impostures.

12. Any person therefore who is skilled in what we have shewn concerning metals, will not be easily caught with vain promises, or false appearances; since the whole tribe of impostors will never be able to communicate either the weight of gold, or the fixity of gold and silver, to any other bodies. By these two marks we may be secur'd against all frauds, plausible reasonings, and spurious, factitious metals. Add, that malleability is likewise generally wanting in these pretended perfect metals.

Affinity of metals when in fusion.

13. All the six metals when fused by fire, in clean vessels, have the same appearance and perfectly resemble mercury, both in respect of colour, density, the sphericity of their drops, the attraction of their parts, their mobility, and manner of running. Hence therefore it seems to follow, that mercury is a metal fused by the smallest fire; that tin requires a greater degree of fire; and that if the atmosphere were hot enough to fuse it, it would be mercury; but mercury which smoaks and casts up a froth: that lead would also be mercury with the next degree of heat, but mercury with certain peculiar properties of frothing and penetrating vessels: so silver and gold are mercury, which require a much greater degree of fire, and remain immutable therein. Copper again is mercury which melts in a much intenser heat, but is changed withal. Lastly, iron becomes mercury in a degree of heat beyond any of the rest; and tho' changeable thereby (q).

Of S A L T S.

Salts called concrete juices.

Characteristic of salts.

1. After metals come salts, by others called concrete juices, as being very simple and contributing to the composition of semi-metals and other minerals.

2. By salt we here mean "a fossil body which melts both in fire and water; and is so simple in its structure, that each particle retains the same nature with the whole, and impresses a sense of taste on the tongue (r)".

(q) This last corollary tends to shew that all the metals are mercury, and that common quicksilver is a metal. How justly it is drawn from the premises deserves to be examin'd. Perhaps we have hitherto no tolerable history of metals, to enable us to draw safe conclusions about their nature. For notwithstanding the numerous experiments hitherto made upon metals by the alchemists, the chemists, and natural philosophers; yet whoever considers the subject attentively, will find we have but a very uncertain knowledge of their respective compositions, and relations: so that till farther enquiry is made, we can encourage no philosopher to attempt the drawing of consequences; which, however specious they appear, may, if faulty, tend to lead us into error, stop enquiry, cramp our faculties, and propagate untimely despair.——Let a full and judicious history of facts be therefore pro-

3. The cured, relating to this difficult and extensive subject; which being duly digested, ranged, and compared together, the true consequences will spontaneously arise of themselves; but if we attempt to force them before the time, it will be no wonder if they should prove abortive.

(r) After metals, the next bodies in order of simplicity, are salts: the definition whereof is as follows:

Salt is a fossil body, fusible by fire, and congelable again in the cold, into little glebes, or crystals; soluble in water, so as to disappear therein, and impressing a sensation of acrimony upon the tongue.

Such is the precise idea of a salt; which agrees to all kinds of salts; and by which a salt is distinguish'd from all other fossil, vegetable and mineral bodies.

3. The natural bodies belonging to this class are, 1. *Common salt*, divided into *sal gemma* or rock salt, that of salt-springs, and sea-salt. 2. Salt-petre. 3. Borax. 4. *Sal-ammoniac*. 5. Alum; and 6. the vague acid of mines.

1. Of COMMON SALT.

1. Fossil or rock-salt, whose purest part they call *sal gemma*, is found in pits or mines in divers parts of the earth, very plentifully, and at great depths; and it is dug from thence in all its perfection.

2. Spring, or fountain-salt, is found mixed in the water, which bubbles out of the ground in divers places; and which when purified and inspissated nearly resembles sea-salt.

3. Sea-salt is diffused thro' all the waters of the ocean, and from thence may be separated, and reduced to crystals, merely by exhalation and purification (s).

Natural history of rock-salt.

(s) *Sal-gemma*, popularly called *rock-salt*, is dug out of mountains, and broke into gleebs or lumps. The finest in Europe is in a mountain of *Catalonia*, not far from *Barcelona*; but there is scarce any part of the earth without it: in *Poland*, *Russia*, &c. there are several mountains thereof.

This salt appears to have been unknown to the ancients. *Pliny*, indeed, gives us some curious things about salts; if we could believe them as true as they are pretty.

The salt-mines in the village *Wilizea*, five leagues from *Cracow*, were first discover'd in 1251; their depth, and capacity, are surprising: within them is found a kind of subterraneous republic, which has its polity, laws, families, and even high-ways, and common carriers; horses and other cattle being kept here to draw the salt to the mouth of the quarry, where it is taken up by engines. These horses, when once they are down, never see the day-light more; but the men take frequent occasions of breathing the village air. When a traveller is arriv'd at the bottom of this strange abyss, where so many people are interr'd alive, and where so many are even born, and have never stirr'd out, he is surprized with a long series of lofty vaults, sustain'd by huge pilasters cut with the chissel; and which being themselves rock-salt, appear by the light of flambeaux, (which are incessantly burning,) as so many crystals, or gems of various colours, casting a lustre which the eye can scarce bear.

These rocks of salt are hewn in form of very large cylinders; the workmen using hammers and chissels, as in our stone-quarries. As soon as the massive pieces are got out of the quarry, they break them into fragments fit to be thrown

4. These into the mill, where they are ground into a coarse flower.

Here are two kinds of *sal gemma*, the one harder and more transparent, which appears to be the more perfectly crystallized. This is the proper *sal gemma*, and is frequently cut like crystal, and form'd into toys, chaplets, little vases, &c. The other is less compact, and only fit for kitchen uses. One of the chief wonders of the place is, that thro' these mountains of salt, and along the very middle of the mine, there runs a rivulet of fresh water, sufficient to supply the inhabitants.

In the salt-mines of the *Upper Hungary*, and the mountains of *Cardenna* in *Catalonia*, the salt-stone is found of various colours; as white, red, blue, green, brilliant, &c.

Natural History of Spring-salt.

The salt extracted from brackish springs, seems either to arise from the salt-water of the sea, receiv'd thro' subterraneous cavities, and deposited there; or from some mineral, or gem salt, lodg'd in the strata of some neighbouring mountains, wash'd down by some rivulet of water, and gather'd here. The way of preparing it, is thus:

Near the spring is built a *saltern*, or boiling-house, furnished with several large flat pans, with each its grate and furnace. Into these the brine is convey'd by pipes, the fire kindled, and in two hours time the liquor begins to granulate, which is known by a thin skin rising at the top, which they skim off into brine-tubs. The sand, which the water yields pretty plentifully, is by the violence of the boiling cast to the sides, where they lade it out into vessels for that purpose. Both this sand and the scum contain salt, which they extract by a future operation.

The Theory of CHEMISTRY.

4. These three species tho' different in their origin, are all of the same nature: 1. they all dissolve with the same quantity of water, viz. three and a quarter of their own weight; 2. resolve spontaneously in the air; 3. produce crystals much alike, viz. cubical, pyramidal, or parallelopipedal, by a quicker or a slower operation; 4. if added to *aqua fortis*, they enable it to dissolve gold; 5. by distillation they yield an acid spirit of the

The sand being removed, they shut up the vent-holes and door, and let the fire go out; and in twelve hours time the salt is precipitated to the bottom, where it grows hard; liquor called *bittern* remaining at top; which being boil'd over again yields more salt.

To make the salt precipitate more readily, they frequently use beef-suet and wine lees, of each an equal quantity; melting them together, and putting an ounce of the mixture on the end of the slice, and turning it round in the liquor till it be all dissolv'd: then, after two hours at most, opening the vent-holes, &c. and quickening the fire, they lade away the liquor; and find the salt lying at the bottom.

Lastly, taking it out, they put it into cribs, like hay-racks; where, after eight hours draining, it is found a hard granulated salt: yet it continues dripping a fortnight longer; and, unless it be frequently stirr'd, becomes rocky.

Natural history of sea-salt.

Sea-salt is thus called because extracted from sea water; being in every part of the ocean, and in every gulph communicating therewith: but in lakes, or other stagnant waters it is scarce found at all. 'Tis this saltiness of the ocean that prevents its growing fetid, and putrifying by the heat of the sun; and yet, notwithstanding all its saltiness, the freshest fishes live and increase therein. It is found in greatest abundance where the sun's heat is the most intense; and the least in the coldest regions.

This sea-water being boil'd, scum'd, and evaporated to the consistence of a brine, (which is prov'd by a new-laid egg's swimming therein) is left to settle; when the salt falls to the bottom, and shoots to the sides in crystals of a cubical figure.

A large quantity of sea-salt is made along the coasts of *France*. There are two kinds of it; the one requiring the sun's heat to bring it to a consistence, and called, from its brown colour, *bay-salt*; the other receiving its consistence from the heat of a fire, called *white salt*: either the one or the other method is practis'd, according to the disposition of the coasts where 'tis made. If they rise in downs, or banks of sand, the salt is made by fire, in

copper or leaden vessels; if the bottom be clayey, the salt is made wholly by the action of the sun. The method of proceeding in each is as follows.

The making of bay-salt.

1. For *bay-salt*. Low marshy grounds, disposed by nature for the reception of the sea-water, when the tide swells, and provided with banks and sluices to retain the same, they call *salt-marshes*. These salt-marshes, the bottoms whereof they ram with great care, are divided into square pits or basons, separated by little dikes; and into these basons, when the season is at hand, they let in the sea water. The salt-season is from the middle of *May* to the end of *August*. The water is admitted to the height of about six inches; after having first let it rest, exposed to the sun for two or three days in a large reservoir, without the works, that it may come in lukewarm. The water being admitted, the sluices are shut, and the rest of the work is left to wind and sun. The surface of the water being struck, and agitated with the direct rays of that luminary, thickens, at first imperceptibly; and becomes at length cover'd over with a slight crust; which continuing to harden, is wholly converted into salt. The water in this state is so hot, that the hand can't be put into it without scalding. When the salt has receiv'd its full coction, they break the crust with a pole; upon which it sinks to the bottom: whence, being dragg'd out again, they leave it in heaps about the pit, to compleat its drying; covering it over with straw or rushes, to secure it from the rain.

Eight, ten, or at most fifteen days, having thus compleated the crystallization, they open the sluices, when the tide rises, for a fresh stock; and thus, alternately, while the season holds.

The making of white sea-salt.

(2) *White sea-salt*. On the flat shores of *Normandy*, they gather a muddy sand, which the rising tide has impregnated with its waters for seven or eight days. This sand being removed into pits for the purpose, discharges itself by degrees of all its water; which filtrates thro' some straw, wherewith the bottom of the pit is fill'd; and trickles into vessels

the same kind; 6. when dissolved in moist air, they deposite a great quantity of earth, and leave an unctuous, sharp, austere liquor behind; 7. they all crackle in the fire; but melt by a stronger degree thereof; 8. remain long fixed therein; 9. nor when pure and unmix'd are they at last changed; nor do they thus yield a spirit, but only a little water. 10. Lastly, they afford no alcali; nor are altered by putrefaction.

2. OF NITRE.

1. Modern nitre, or salt-petre, which forms prismatic crystals, of eight sides, is a sort of semi-fossil, procured from an acrimonious nitrous earth; it is fusible by a moderate fire, evaporates its water with difficulty, is considerably fixed; when fused with any inflammable matter, it deflagrates; and dissolves in six times and one third of its own weight of water (1).

Salt petre.

2. This nitrous disposition of earth and stones, owes its origin to the excrement of animals, and the putrefied carcases thereof, especially such as do not use sea-salt, particularly birds; with the accession of the natural un-wash'd ashes of burnt vegetables, and quicklime. The salt thus prepared, being diluted with a large quantity of water, and strained thro' sand, shoots into these octogonal crystals. According to *Hoffman* (u), nitre is generated of a fat alkaline earth, and air (x).

Origin of it.

sels set on purpose to receive it. This water they ladle out into leaden boilers, with fires under them. As soon as it begins to boil, they take off the skin, which rises in great quantity; and in proportion, as it diminishes, throw in more water, which they continue to skim as before. When it thickens, they keep it continually stirring; and when the grain is form'd, take it off the fire. This done, it is put into large ozier-baskets, where it stands some time to purify, and drain itself of its remaining humidity: when dry, it is laid on heaps, and thence carried to the magazines.

They have also a method of refining *bay-salt* into *rubite-salt*, by boiling it in large flat caldrons; which not only lessens its acrimony, and alters its colour, but is also found to increase the quantity.

These three salts scarce differ in any thing, but the place they are found in; unless perhaps in the degree of purity and dryness. They have the same effects on gold, which is not dissolvable by any other salt without them. They have the same effect, likewise in the making of spirit of salt, in fertilizing barren grounds, in seasoning, pickling, and other culinary uses; and their taste is the same. In reality, it seems probable that they are one and the same salt, and that sea-salt has its rise from *sal gemmae*.

These are *perfect salts*, being of all others the most fixed, and immutable, both in the

P. 2 *Of* fire, and the human body: salt-petre loses its nature in the body; sal-ammoniac, borax, &c. shews no signs of themselves in the urine; but sea-salt may be always extracted from it; so that this must be allow'd an exceedingly simple and unchangeable body.

The virtues and uses of common salt.

Its power of preserving animal substances uncorrupted is generally known; and for the same purpose it is also used by chemists to keep vegetables from putrefying in long digestions. Physicians attribute similar virtues to it in the body; viz. checking the fermentation, and preventing any tendency to putrefaction of the aliment in the stomach. They likewise allow that it carries its virtues into the blood and vessels; so as moderately to dry, warm, deterge, attenuate, stimulate, and prevent corruption of the solids and fluids.

(1) *Salt-petre*, or *nitre*, is known by these characters. 1. Its crystals are of a prismatic figure, with hexagonal bases. 2. It dissolves by fire more readily than any other salt. 3. It is the coldest of all salts, and affects the tongue much like ice; having a peculiar pungency. 4. It is the basis of *aqua fortis*, and dissolves silver.

(u) *Hoffm. de Aqu. Min.* Tom. II. p. 42. The author here quoted says, that nitre is not a fossil or mineral salt, but properly belongs to the vegetable kingdom, and the atmosphere; whence it comes to be lodg'd in a fat alkaline earth,

3. OF BORAX.

Borax.

Borax, or *Chrysocola*, which is of various figures, requires a large quantity of boiling water, viz. 20 times its weight, to dissolve it; its taste is somewhat

earth, as a proper receptacle; and that it may be extracted from the air, by exposing quick-lime, pot-ash, or any alkaline salt or earth thereto, in a place well defended from the sun and rain*.

Natural history of nitre.

(x) It is controverted among naturalists, whether *salt-petre* be a fossil, or an animal salt; some holding it producible from the mere excrement of animals. But it is more just to say, that it is produced from those excrements intermix'd with the alkaline salts of vegetables, or alkaline earths, which seem to constitute it a salt of a middle kind between fossil and animal.

M. Homborg observes, that all the salt-petre we now have, is either obtain'd from earths moisten'd, and manur'd with the excrements of animals; or from old walls, and the plaster of ruin'd buildings, impregnated with the excrementitious *effluvia* of the animals that inhabited them.

Salt-petre is found in several places in the kingdom of *Persia*, &c. particularly about *Agra*, in villages anciently populous, but now desert. 'Tis also found in some places about the river *Volga*.

The glebe, or earth, from which it is procured, is of three different kinds; black, yellow, and white: the method of procuring it is thus. Two shallow pits are dug, one of which they fill up with the mineral earth; turning water upon it for some time, and then treading it with their feet into the consistence of a pap; and letting it stand two or three days for the water to imbibe, and extract all the salt. They then shift the water into another pit; where standing some time, it shoots, and crystallizes into rough salt-petre.

It is also made in *France*, particularly in the arsenal at *Paris*, where there is a corporation of salt-petre makers appointed for the purpose. The materials are chiefly collected from old buildings, ruins, plaster, dove-houses, stables, &c.

These materials, or any proper earth, being found by the taste, or otherwise, to contain nitre; they first grind them to powder, if they are hard, and then putting it into vats

they pour cold or hot water thereon, and stir the mass afterwards suffering the whole to rest, till the water has saturated itself with the salt; then they draw it off by a tap into another vessel, and pour fresh water upon the remainder; repeating the operation till no more salt can be extracted. Sometimes instead of water they use a lixivium of wood-ashes or pot-ash, when they suspect the nitre inclin'd to volatility, or indisposed to assume a body. The several liquors, thus obtain'd, they boil to a due consistence, or strength; with care to skim it all the while; then they run it warm into other vessels, and let it stand till perfectly cold; by which means the sea-salt shoots, and separates from the nitrous solution, and falls to the bottom in small grains. And now the nitrous liquor being drawn off, they suffer it to shoot into its own crystals in the cold. After these are all shot, they draw off the liquor, and boil it again; then suffer it to shoot as before, and repeat this process till it will shoot no longer. The liquor thus left behind is unctuous to the touch, acrid, and bitter. 'Tis called *mother*, or the *mother liquor of nitre*; because being sprinkled upon proper earth, it disposes it to generate fresh nitre. And thus rough nitre is procurable by art; and might be advantageously made in some countries, by a proper contrivance, in the way of an artificial mineral-work.

The manner of procuring salt-petre in the East.

This salt sometimes offers itself spontaneously, in the form of an efflorescence, upon old walls, or buildings not much exposed to the sun and rain; and may thus be readily swept off, and purified for use. And much after the same manner it is found upon the ground, in some of the eastern parts of the world abounding with woods standing upon a declivity; where the leaves, and refuse vegetable matters, corrupting upon the surface of the earth, seem to generate nitre; which being wash'd down the declivity by the rains, and the moisture afterwards soak'd into the ground, or dried up by the sun, leaves the salt behind in small dirty grains, or dusky spangles, that are easily swept together in heaps†.

How

* See *New Experiments and Observations upon Mineral Waters*, p. 45.

† See M. Lemery upon the Subject. *Mem. de l'Acad. an*, 1717. p. 36, and 156.

somewhat bitterish, which however sweetens at going off; it easily fuses by fire, and at the same time rises into a large blister, and thus lets go a considerable quantity of water: the remainder subsides in form of fair glass. It is a great promoter of the fusion of other bodies mixed with it, and thus becomes of use in the soldering of metals, especially gold (y).

How refined.

The way of refining this salt is only to boil it in fresh water, skim it, and pass it through flannel, and suffer the liquor to shoot slowly; repeating the operation several times, if the nitre be required perfectly fine, and clear of common salt. There is a loss upon the refining; for earthy matter, and mother appear to be deposited every time. It is known to be pure, when it will not crackle if thrown into the fire, but yields a vivid flame, and a strong detonation upon live charcoal, without leaving much fix'd matter behind. When purified nitre is melted, and poured into a proper vessel, it concretes into a solid mass, and is call'd rock-nitre: and this is all the preparation it requires for the finer uses.

Its virtues and uses.

Nitre has, in some measure, the same virtues and uses with common salt, as to preserving or preventing corruption, though not so strongly. Its peculiar use in making gunpowder, and entering the composition of fireworks, is well known. Physicians esteem it cooling, quenching, and proper in burning fevers. It is used in making the white glass, and as a flux to ores. Its uses in chemistry and medicine will be shewn hereafter in the practical part of this work.

Natural history of borax.

(y) The ancient borax appears to have been a kind of verdigrease, or at least a different thing from the modern borax; as we may find upon comparing the accounts given of it by *Pliny*, *Dioscorides*, and *Galen*. *Pliny* speaks of borax at large in his *Nat. Hist.* L. xxxiii. c. 5. He divides borax into native and factitious: the native, according to him, is a kind of muddy juice, running in gold, silver, and copper, and even lead-mines; which being congeal'd and harden'd by the winter's cold, arrives at the consistences of a pumice. As to the artificial, he says, it is made by pouring water into the vein of a mine all the winter long, till *June*; and then leaving it to dry, and harden for three months, so that the borax of *Pliny* should be no more than the mineral corrupted. He adds, that the borax becomes yellow, white, green, or black, according to the mine it is found in.

The moderns also have two kinds of borax tho' they differ only as being refined, or un-

refin'd. The rough, or unrefin'd borax goes by the name of *tincar* and *tincal*, an *Arabic* term, signifying a species of salt that serves to solder gold; thus corresponding to the *chrysocola* of the *Greeks*. It is brought to us in small lumps, or thick prismatic crystals, of a dark green, colour, foul, earthy, unctuous, and having a particular rank smell. It is pack'd up in large skins, like dress'd hides, or thick parchment, called duffers. 'Tis found in several parts of *Persia*, and the empire of the *Great Mogul*; where, in several mines, but particularly those of copper, there runs a saline turbid water of a greyish colour, which they carefully collect and evaporate to a proper consistence for forming into a paste with the slime or mud of the streams wherein it flows; and then mixing it up with animal fat, or any greasy matter, they bury it in pits dug in the earth; and leave it in this state for several months to acquire a body, and grow hard; and thus it seems to shoot and acquire that form in which it is brought to us.

The refining of borax.

The *Venetians* formerly used to refine this rough borax, and made a considerable advantage of it, being then the only venders; whence it was commonly called *Venetian borax*. But now for some time this trade has been chiefly in the hands of the *Dutch*; tho' within these few years we have also begun to refine borax in *England*. The manner of doing it has been kept as a lucrative secret, and is not easy to find out; the salt being of a very odd and particular nature, and requiring a particular treatment to refine it. The foul greasy matter is apt to adhere closely with it, so as almost to enter its composition; and contrary to the nature of other salts, it will only shoot in its proper crystals, whilst kept hot and defended from the external air for several days. The best manner of refining it is this. First, dissolve it, by boiling it in a copper, with above twenty times its weight of water; then cover the copper, let the fire go out of itself, and the whole grow perfectly cold; by which means the salt will shoot away from much of its filth, the grosser part whereof sinks to the bottom, and the lighter part rises to the top. The salt, now of a dirty yellow colour, is to be taken

4. Of SAL-AMMONIAC.

Sal Ammo-
niacum.
Cyrenaic salt.

Sal-Ammoniac, or *Sal-Arenarius*, generated in the dry sandy parts of the sultry deserts of *Lybia*; being probably the *Sal-Cyrenaicum* of the ancients, found so plentifully about the temple of *Ammon*; which from the marks of its goodness given by *Pliny*, appears to have been perfectly like the modern kind (2). The like is also thrown out of burning mountains, in various parts of the earth: that of mount *Vesuvius* is reputed the best even to this day. This species therefore belongs to the fossil tribe; tho' that now brought from *Egypt* be reputed of the animal kind. 'Tis probable it may derive its origin every where from foot (a).

Origin from
foot.

taken out as clean as possible. All the dirt, still containing much salt, is to be boil'd over again, and suffer'd to shoot in the same manner. When a sufficient quantity of this yellow salt is obtain'd, it must again be boil'd in fair water, and shot a second time; whereby it still becomes purer: but to make it perfectly fine, this second, or even the third salt is to be boil'd again, with the addition of a large proportion of the lixivium of pot-ash, and the whites of eggs, as in the common way of clarifying; with care to take off the scum as it rises, and to pass the hot liquor thro' a flannel strainer; by which means the whole solution ought to be render'd perfectly bright, and considerably pale before it is set to be shot for refined borax. It shoots best in a copper vessel, close cover'd at the top, so as not to admit the external air; and should be kept in this state, till perfectly cold, before it is open'd; which, if the quantity be large, will require five or six days. To obtain the finer and larger shoots, brass wires may be let into the copper, thro' holes bored in the lid, at the distance of two inches from each other. Many curious phenomena arise in this process; some of them, perhaps, of considerable use; but it is a tedious and laborious, tho' a profitable operation. Scarce any operator should expect to succeed in the refining of borax, at the first trial; a regard is required to so many unexpected circumstances.

Borax requires to be perfectly refined for medicinal use; but for many others, where beauty and purity are not necessary, the rough sort may serve as well, and save charges. The precise figure of its shoot, when perfectly refin'd, seems not to be determined, and indeed requires a particular experiment for the purpose, all the crystals obtain'd in the common way, being imperfect at one end.

Its virtues and uses.

It is of excellent use in the business of sol-

ders, as occasioning metals to run readily, and lay hold of each other; tho' in some of these cases, its place may be supplied by glass, to which it has a near relation. 'Tis also an admirable flux for metals, and metallic minerals. It is almost indispensably necessary in many arts where metals are concern'd. The dyers use it to give a gloss to silks; and it might perhaps have new uses in the arts of glass, enamelling, and counterfeit gems*. Physicians esteem it stimulating, diuretic, and emmenagogic; and use it chiefly in female disorders; particularly to promote delivery, and bring away the secundines. Externally, it is a safe cosmetic; and preferable to the dangerous preparations of lead, mercury, and bismuth, for the purpose of a beautifier.

(*) There may be room to suspect that the text of *Pliny* has been a little interpolated in this place, by some transcriber, acquainted with the sal-ammoniac which is factitious; as the sentence does not agree well with the place, nor make *Pliny* consistent with other ancient writers upon the subject. But this belongs to the critics.

The natural history of sal-ammoniac.

(a) The ancient sal-ammoniac appears to have been different from the modern, if we may credit *Dioscorides*, who reckons it among the kinds of alimentary salt, and describes it as a hard, transparent, white, fissile, mineral substance; which seems to make it the same as our rock-salt. The name *ammoniac* may refer to its being found in sand, or near the temple of *Jupiter Ammon* in *Lybia*, anciently much frequented; and this salt was supposed to be made from the urine of camels, &c. there deposited in the sands: whether our sal-ammoniac be thus found is uncertain. Its characters are these: (1) It cools water. (2) It turns *aqua fortis* into *aqua regia*. (3) It remains fix'd in a gentle fire, but sublimes in a strong one. (4) Its taste is quicker

* See *Chem. Lectures*, Lect. xx. Exper. iii.

5. Of A L U M.

1. *Alum* is a real fossil, procured either from a hard, flaky stone, found deep under ground, and pregnant with sulphur and bitumen, so as easily to take fire; or from a bituminous and combustible earth, which yields a noxious flame, with a sulphureous stench. If the latter matter be employed for this purpose, they leave it a month exposed to the open air; whereby it crumbles into powder; and thus becomes disposed for the generation of alum, which before it was not. If the former, or stony substance, be used; after first exposing it to the air, they calcine it; and in the operation it yields a flame, which shews that it contained a sulphur. *Alum, its origin.*

2. After this preparation of the matter, either by air alone, if it be earth, or by fire and air, if it be stone; they dissolve it in water, and precipitate it, by adding to it a fix'd, or volatile alcali, which also raises an effervescence: whence the acid uniting with the alcali, prevails, and produces a new salt, thus generated from the air, the alcali and the fossil matter together. *Generation.*

quicker than that of sea-salt, and resembles that of urine.

A native sal-ammoniac is also said to be found in certain sulphur-rocks near *Puteoli* in *Italy*, and near the mouths of several volcano's, or burning mountains. But we have never seen any true sal-ammoniac of this kind; 'tis possible it may be thus produced from soot, as the author intimates: but the salt brought from these places seems to be a sublimation of common salt, or saline fumes, raised by the great fires condensing upon the adjacent stones and rocks, in form of a white efflorescence; and being thus gather'd, passes under the name of sal-ammoniac, which it may resemble; so that experiments should be made upon it to determine whether it be true sal-ammoniac.

It seems to be pretty certain, that the true sal-ammoniac, now in use, is an artificial thing; the principal part whereof is made in *Egypt* and *Syria*, and thence distributed thro' *Europe*. It comes to us in pretty large orbicular cakes, flat, or a little concave on one side, and convex on the other, with a lump rising in the middle. They are about six inches over, and two or three deep; of a grey colour on the out-side, and sometimes black, as if tarnished with soot; but appearing white, crystalline, and break'd, or striated, when broke. There have been great contests as to the generation of this salt; but they seem to be now ended by the accounts of the missionaries and the *French* academicians*.

3. The

Sal-ammoniac, how made.

It is made in the following manner at *Damascus* in the *Delta*.

For want of other fuel, the natives commonly burn the dung of animals, but especially camels; which they make up into a kind of turf with straw, and dry it. This, in burning, affords a quantity of soot, which they carefully collect, and preserve for the purpose. This soot, they sprinkle with a solution of salt, dissolv'd in camels urine; then charge large subliming glasses with it, observing not to fill about two thirds of each vessel: these they set in a subliming-furnace, built of brick and clay, so as to cover them as high as the matter reaches; then they make a fire underneath, and proceed in the work after the common method of sublimation; whereby a cake of salt is thrown up to the top of each vessel; a blackish mass remaining behind at the bottom. And hence the figure of the cake corresponds to the shape and make of the heads of the glasses, which are broke to take out the salt; after the manner practised for the refining of camphire in *England* and *Holland*. It is purified by solution in water, filtration, and gentle evaporation.

Its virtues and uses.

It is made great use of in chemistry, as will appear hereafter; and in alchemy for obtaining the supposed mercuries of metals. It is of service in the art of tinning, by making tin adhere to iron; and of use in soldering. It is likewise of great use in dyeing; and has considerable virtues in physic†.

* See the *Memoirs of the Jesuits in the Levant*, printed at Paris in 1723. and *M. Lemery's Paper upon the Origin of Sal-Ammoniac*. *Memoir. de l'Acad. an. 1720. p. 66.* And *Jour. de Trevoux*. Dec. 1717.

† See its history in the practical part of this work.

The Theory of CHEMISTRY.

3. The matter thus precipitated, is then separated from the lixivium floating above it, dissolved in boiling water, inspissated in a leaden vessel, and now put into a cask, and left to rest; by which means it yields white or reddish aluminous crystals, of an octagonal figure, and a sweet austere taste, not apt to liquify in the air, and requiring fourteen times their weight of water to dissolve them.

4. The acid in this salt appears the same, in almost all respects, with the acid vapour collected from burning sulphur. What remains, after the expulsion of this acid, is a fæculent matter, which affords great quantity of a light subtile earth resembling bole. This being calcined with three times its quantity of charcoal, yields the *Phosphorus* of M. *Homburg*: and thence appears to have a peculiar disposition for taking fire in the air (b).

6. Of the VAGUE ACID.

Vague acid.

*Forms various
fossils.*

*Affinity with
fume of sul-
phur.*

1. The vague volatile liquid acid, found perhaps every where in mines. This making with fossil oil, *Petroleum*, *Oleum terræ*, or the like, probably constitutes the various sorts of native fossil, transparent sulphurs, denominated *Viva*; uniting with semi metals it forms cinnabar, antimony, and other fossils both solid and fluid: uniting with metals, it forms divers kinds of vitriols: with calcareous earths different alums: and lastly with pyrites, which is the *matrix* of vitriol, calcin'd in a wood fire, it produces common sulphur.

2. May not this be held much of the same nature with that acid which burning sulphur diffuses from its blue flame, so suffocating and fatal to all animals? 'Tis certain the analysis seems to indicate as much. And hence this may probably be looked upon as a male salt, and serving to impregnate the female salts and earths (c).

Natural history of Alum.

(b) Alum is distinguish'd into natural and factitious: the natural is rare; all that we commonly use is artificial, which differs only according to the places where it is made. Alum has a sharp rough styptic taste, its crystals are octagonal, four of the sides being hexagonal, and the other four triangular surfaces. It easily melts over the fire, and rises in blisters.

England, Italy, and Flanders, are the countries where alum is principally produced. The *English* alum is made from a bluish mineral stone, almost like slate, frequent in the hills of *Yorkshire* and *Lancashire*. This stone they calcine on a hearth or kiln; then steep it successively in several pits of water: then boil it about twenty-four hours. Lastly, letting it stand for about two hours; the impurities subside, and leave a pure liquor; which, removed into a cooler, and some urine, or kelp-liquor added to it, begins in three or four days, to gather into a mass: which being taken out, wash'd, dissolv'd, and shot over again, is fit for use.

C O R O L-

In the alum-works at *Civita Vecchia*, the process is somewhat different. The stone, which is of a ruddy hue, being calcined, they boil and dissolve the calx in water; which imbibing the alum, separates it from the useless earth. Lastly, leaving the water thus impregnated, to stand for some days, it crystallizes of itself, and makes what they call, *rock-alum*.

At *Solfatara*, near *Puteoli* in *Italy*, is a considerable plain, the soil whereof is saline; and so hot that the hand cannot long bear it. From the surface in summer-time, there arises a sort of flower, or saltish dust; which being swept up, and cast into the leaden cisterns of water at the bottom of the plain, the heat of the ground alone where they lie, evaporates the water, and leaves an alum behind.

Its uses.

It is much used in dying; and in medicine as a styptic and astringent.

(c) There seems to be a certain *vague salt*, or *acid*, diffused in all parts of the earth; which, when alone, is volatile; but when it has a body, or proper subject to adhere in becomes fixed. The idea of this salt we are

COROLLARY.

Hence it follows, that in the formation of fossil salts, nature seems to use three kinds of acids (*d*); viz. 1. Spirit of salt; 2. Spirit of nitre, both pretty copiously; and 3. Spirit of sulphur, more sparingly; and besides these, water and earth (*e*). *Principles of fossil salts.*

Of SULPHURS.

1. The third class of fossils consists chiefly of sulphurs: under which some other bodies are rank'd.

2. " Sulphur is a fossil body, which is hard when cold, and easily reducible to powder; but melts by a moderate heat like wax; may be totally sublimed by fire in a close vessel, without alteration; when in a state of fusion by fire, if the air be admitted, it burns, and flies totally off, yielding a blue flame, and a volatile vapour, noxious to animals. *Characters of sulphur.*

3. Sulphur is sometimes, tho' rarely, and only in small quantities, procured native from the earth; when it is either found transparent, and yellow like amber; or transparent and red like the ruby, and then called golden sulphur; *Species of sulphur.*

at a loss how to convey, otherwise than by its effects; it seems to come nearest the nature of spirit of sulphur *per campanam*; and is discover'd in all sulphur, in all vitriol, in all alum, in all nitre, in all fossil coals, &c. This same acid is, perhaps, that pernicious fume, or damp found in mines, and the smoke which flies from bituminous turf, &c.

This we look upon as an indeterminate principle, distributed thro' every part of the globe, both inside and out. 'Tis this acid that dissolves iron and copper near some hot baths; this, that meeting with fossil or rock-oil, coagulates and converts it into sulphur; this, that being received into the earthy part of the alum, or the *lapis calcarius*, converts it into *alum*: this, in fine, that, insinuating into the substance of iron, produces *green vitriol*; or into that of copper, *blue vitriol*, &c.

The doctrine here deliver'd of a *vague acid*, may seem a little hypothetical, till the actual separate existence of such an acid be shewn; of which we do not know any clear instances. The argument for it stands thus; we find several mineral bodies that afford acids upon their analysis; or appear to contain acids; and therefore nature makes use of these acids in the composition of such mineral bodies: but to render this argument conclusive, the acids should be shewn to exist in the earth, and instances be produced of nature's working in this manner, with the several steps of the process: but instead of this direct proof, we

only find a prejudg'd theory in authors, supported by probable reasonings, and a plausible solution of phenomena, which may be no more than a bare accommodation to the mind.

(*d*) It would add a kind of confirmation to this corollary, if it could be shewn that these three acids are to be found separately existing under any of those forms in which we obtain them by art. Where do we find any truly acid waters, liquors, or fumes, either in mines, or out of them?

(*e*) Fossil salts left to shoot, or crystallize, assume certain figures, which are usually attributed to them as their proper figures; tho' sometimes supposed to be the figures of the acids of those same salts. These figures are, in sea-salt, cubes; in sal-gem, parallelopipeds; in salt-petre, a sort of needle form; in alum, triangles, with the points blunted; in borax, flattened ovals; in sal-ammoniac, branchy needles, &c. Yet upon examining the configuration of these salts, it will appear, that such figures do by no means belong either to the salts, or the acids procurable from them; but rather to the alkalies, whereby they are dissolv'd, and which serve them as bases. And hence the same acid assumes different figures, according to the different alkalies it is saturated with before crystallization. Thus, spirit of nitre, after dissolving copper, shoots into hexagons; after dissolving iron, into irregular squares; after dissolving silver, into triangular, dented plates, &c.

Common, factitious.
From pyrites.

or not transparent, which last again is either yellow, ash-colour'd, or mixed of divers colours, and called *Sulphur virum*, or virgin-sulphur. But all that is fold in the shops throughout *Europe*, is factitious; being obtained by art from the pyrites, wherein it scarce seems to have pre-existed; since its *matrix*, or ore, the pyrites, being detained in the fire, yields no sulphur, but an acid liquor, like the acid of vitriol. Whereas the same *Pyrites* being duly prepared, and then long exposed to a vehement fire, gradually softens, calcines, cracks, and exudes a true sulphur.

4. Sometimes indeed the sulphur is found ready prepar'd in the *pyrites*; so that upon being ignited the sulphur trickles from the containing vessels placed aslope for the purpose, and is caught in receivers. And hence the ore or *matrix* both of sulphur and vitriol, is the same. And thus may sulphur be artificially compounded of the spirit of vitriol, alum or sulphur *per campanam*, and a vegetable oily matter combined together. So that sulphur is not improperly called by the chemists *Resina terra*, or *Resin of the earth*.

5. Being separated by repeated fusions, both from the impurities which rise to the top and sink to the bottom, and poured into wooden moulds of a cylindrical figure, it is exposed to sale; and from its colour, which resembles that of the citron, is called *Sulphur citrinum* (f).

Natural history of sulphur.

(f) There are two principal kinds of sulphur, tho' not greatly differing from each other; *viz.* the native, and the factitious. Native sulphur is that which never felt the fire; and factitious is that obtain'd by fire.

The native sulphur, otherwise called *sulphur virum*, is of two kinds; the one transparent, and of a shining yellow, green, or red colour; which is found near the gold-mines in *Peru*, *Switzerland*, &c. the other is opaque, and found either in shining green, or yellow lumps, or gleebs, or in form of a clayish earth, of a light grey or yellow colour; and found near vulcano's, particularly *Vesuvius* and *Etna*; sulphureous springs, as those of *Aix la Chapelle*, &c. and in several parts both of *Europe* and *America*.

The factitious sulphur is obtain'd in different ways at different places. In some parts of *Italy* there are a kind of sulphur-mines, containing a white argillaceous earth, mix'd with blue veins, which they dig up, put into large earthen vessels, and get sulphur out by a kind of distillation, with an earthen cucurbit and receiver; tho' this is no more than an ingenious contrivance to separate the sulphur from the ore by fusion, and make it rise, so as to run liquid into the inclined receivers. What remains in the cucurbits after the operation, is a red calx, which they throw away.

Much after the same manner they separate sulphur near *Liege*, from a kind of pyrites;

looking like lead ore; which is there dug up, broke to pieces, and put into large square cucurbits of earth, with narrow mouths. These vessels they place in an inclined posture in a furnace; whereby the melted sulphur is made to run out into leaden receivers, fill'd to a proper height with water: the substance that remains in the cucurbit contains a considerable proportion of vitriol. If the sulphur be foul at the first operation, they melt it again in iron vessels, adding to it a little linseed oil; then pour it into hollow cylinders of iron greased on the inside, whereby it is form'd into rolls. The sulphur thus procur'd, is either yellow or greenish; the latter is preferred for some uses, as containing a vitriolic salt. It seems to be best purified by sublimation, which raises it in the form of flowers, commonly called flower of brimstone.

Its virtues and uses.

It is used both internally and externally in medicine; and to great advantage in cutaneous disorders. Its uses in making gunpowder, matches, fire-works, &c. are sufficiently known. It has numerous uses in chemistry. Its fumes check, or prevent fermentation; for which purpose 'tis used by the wine-coopers, &c. It has an electrical virtue. The light it affords in burning makes objects appear ghastly; and on this account perhaps it was anciently burnt in expiations, and other sacred rights, and came to be called *Osior*.

Of

Of ORPIMENT.

1. Orpiment in many respects resembles sulphur; being friable, fusible, easily inflammable, and in burning yielding a sulphurous stench, tho' not a volatile acid one. Withal it is inert and harmless; or not so pernicious to animals as is vulgarly pretended. It turns red by fusion, and in that state affords a volatile emetic matter, improperly called yellow arsenic.

Orpiment.

2. The original native orpiment being fused in a close vessel, produces a brittle mass, which is easily reduced to powder, and appears with the brightness of *Minium*; being not very acrimonious, and consequently not very poisonous, tho' called both by ancients and moderns *realgar*, *red arsenic*, and *sandaraca*: which confusion of names has given occasion to several errors (g).

Citrine arsenic.

Realgar, red arsenic, sandaraca.

Of ARSENIC.

1. The poisonous arsenic is a white crystalline, ponderous, pulverable body, and but of late invention; being unknown 200 years ago. It is an artificial substance, made by melting cobalt with fix'd alkali and flints, in the preparation of smalt. The flower which rises in this operation affords a white crude arsenic; which being fused in a close vessel, by a vehement fire, produces the common white shop-arsenic (b).

Arsenic.

2. If this arsenical flower of cobalt be fused with a tenth part of its quantity of common sulphur, it produces the yellow, poisonous arsenic; which should be carefully distinguished from orpiment, as being of a most deadly quality.

White arsenic.

Yellow arsenic.

Q 2

Natural history of orpiment, or auripigmentum.

(g) By orpiment we understand a natural scaly mineral substance or glebe. It is extremely flaky like talc; tho' its little scales are easily separated from each other. It is of three kinds with regard to colour; viz.

(1) Gold-coloured, or yellow. (2) Red, or cinabarine, mix'd with yellow; and, (3) Greenish or yellowish, mix'd with a large proportion of earth, and therefore the coarsest. All the species are found in the mines of gold, silver, and copper. But the orpiment we commonly meet with is the yellow sort. Its taste is very little if at all acrimonious; it dissolves in oil, it flames in the fire, and then yields a garlick odour; by sublimation it yields flowers like those of sulphur, leaving a hard red mass, or kind of regulus, at the bottom of the subliming-vessel; but if urged with a strong fire, this mass also seems to rise, and concretes on the upper part of the vessel, into a beautiful red, transparent substance, like a ruby; leaving only a small proportion of metallic earth behind. Its fumes in burning being receiv'd by copper, render the metal white and brittle; which may give suspicion of an arsenical quality. And perhaps it is of a mix'd nature betwixt common sulphur and antimony, or

betwixt sulphur and the milder arsenical substances: but its real nature is not hitherto sufficiently determined; though Dr. Hoffman has bestow'd some pains in examining it; and produces arguments to prove it innocent, not only from chemical experiments, but also trials made upon dogs: but both these kinds of trials we know may deceive, or sometimes be fatally transferred from one subject to another. And under this uncertainty we cannot advise the giving it internally; though we suspect it is frequently given by certain people, sometimes with good, but often with bad effects.

Its uses.

It is commonly used by painters for a gold-colour; and as a depilator with quick-lime at the bagnio's; it is also an ingredient in the making of shot, and in the sympathetic inks, which by their fumes render certain invisible inks conspicuous. We have seen it in flakes of a most vivid, beautifully red, green, and yellow transparent colours, brought from abroad, in hopes of obtaining gold from it; but the experiment did not answer.

(b) V. *Kunkel de Arte Vitriaria*, where the furnace for this purpose is described at large.

* See Hoffman. *Observat. Phys. Chym.* p. 259, 267.

Red arsenic.

3. The same flower of cobalt being fused with a fifth part of sulphur, produces the red poisonous arsenic of the moderns; which must be well distinguished from that of the ancients, for the reasons above specified (i).

4. In effect, the modern arsenic scarce seems to be a true sulphur, but rather has a peculiar and specific nature, which distinguishes it from all other bodies; being mortal to all animals, and not easy to be reduced to any class of

Natural history of cobalt, or mother of arsenic.

(i) As arsenics are obtain'd from cobalt, the natural history of this mineral should first be traced. The German cobalt is a ponderous, hard, fossil substance, or imperfect ore, of a blackish colour, somewhat resembling a kind of pyrites, or ore of antimony. It emits a strong sulphurous smell in burning; and is sometimes mix'd with copper, but most commonly with silver. It is dug up in large lumps from mines in Saxony and Bohemia, but particularly near Goslar. Cobalt is also said to be found in England, and particularly in the Mendip hills. It is a valuable, tho' poisonous mineral, and well worth enquiring after. There is reason to believe it may be found in the northern parts of Britain. It has a violent corrosive quality, so as sometimes to ulcerate the hands and feet of the miners; and if taken into the body proves mortal to all the known animals.

Its uses.

It has been already observed, that the three kinds of arsenic are prepared from cobalt. It likewise is the foundation of *zaffer* or *smalt*, and some other of the blues used in painting, enamelling, washing, starching, &c. so as to prove a very advantageous commodity. The way of treating cobalt for this purpose is describ'd by Kunkel in his notes upon Neri's art of glass. The process is this: They first roast or calcine the cobalt in a reverberating furnace, so built as that the flame of the fire may pass over the matter, and keep it ignited. The flame in passing over the cobalt is blue, and carries off a copious fume, which is convey'd from the top of the furnace into a large wooden funnel, some scores of yards long; to the inside whereof a great part of the fume adheres, in form of a whitish foot. This funnel the workmen sweep once in six months, and preserve the foot; of which the several kinds of arsenic are made, in the manner below mention'd. The cobalt, after being thus roasted, is powder'd and calcin'd a second, or even a third time, till the fumes are sufficiently discharged. Lastly, it is finely ground, with twice or thrice its weight of pulverized flint, and sprinkled with water; whereupon it soon turns by melting to a mass called *zaffer*.

Two parts of this calcined cobalt being melted with one part of pot-ash, and three of common salt, it turns to a dark, blue, glassy, crystalline matter, called *smalt*, or the blue enamel. The white arsenic is made by subliming the foot or flowers of cobalt in an iron vessel; or by bare melting it in a close crucible, which gives it a kind of vitreous body. Yellow arsenic is made by subliming, or melting the same foot with a tenth part of sulphur. Red arsenic is made by subliming or melting the same foot with a small proportion of copper-flag, or two parts of sulphur to ten of the foot.

The nature and uses of arsenic.

White arsenic is totally volatile in the fire; it does not flame like cobalt, or red arsenic, as containing no sulphur; its substance or fumes whiten copper, but render it brittle; 'tis one of the strongest poisons. Taken internally, it produces horrid symptoms, as dejection, fainting, stupor, delirium, convulsions, palsy, burning in the stomach, cold sweats; but the following seem particular to this kind of poison, *viz.* erosion of the stomach, so as to leave its coats extremely thin and flaccid in some places; perforation of the intestines, quick swelling, and sphacelation, and putrefaction of the parts of the body after death; but more particularly the parts of generation. If death does not ensue, the person is apt to grow hectic, paralytic, or maniacal. But notwithstanding the numerous fatal instances of this poison, some are bold enough to give it as a medicine, particularly in obstinate intermitting fevers; but this we take to be a monstrous and most detestable practice; as the remedy is infinitely worse than the disease. And tho' the white arsenic be the most fatal and deadly, yet the yellow and red are almost as bad: nor do we know any way of rendering arsenic medicinal, nor of any good antidote against this poison*. Arsenic is frequently used as a poison to animals, especially rats that infest ships; but even this practice is not safe to the sailors. Melted with copper it makes an artificial metal, called alchymy, now pretty much disused, as being unwholesome, or poisonous. It is always to be handled or treated with the greatest

* See Stahl's *Archæater Antibiater*.

of known bodies; tho' more resembling sulphur than any other: and for this reason we rank it under this head (*k*).

Of BITUMINOUS SULPHURS.

1. Nearly resembling the nature of sulphur, are those unctuous bodies which spontaneously issue from the ground, in the composition whereof sulphur appears to have the predominant part. Such particularly are the following (*l*).

Petroleum, or rock-oil, whose name discovers its nature and origin; it resembles melted *Bitumen*, or is perhaps separated from it, and trickles out of rocks: tis thin, light, of a strong smell, and totally inflammable; it is frequently found swimming on spring-water, and so nearly resembles a distilled oil in several respects, that many have thought it the product of fire by some subterraneous operation. It is frequently considered as a liquid bitumen; from which, however, it differs in colour, smell, and transparency.

2. *Naphtha* (*m*) is much like petrol (*n*), only thinner, whiter, more easily inflammable, and maintains its flames longer; being difficult to be extinguish'd. It is the purest and subtlest part of bitumen (*o*). Naphtha.

3. *Asphaltum*, as it is called by the *Greeks*, by the *Latins* *Bitumen*, is thicker than naphtha, or petrol, very viscid, or tenacious, tho' at first it is in some measure fluid; whilst it retains its nature, it generally swims on water; Bitumen.
Asphaltum.

and greatest caution. The white is used in glass-making, to make the glass transparent; by potters in their white glazing; by enamellers to glaze or cover their metallic colours. The yellow and red are used by painters in their flesh-colours, browns, and yellows. The smallest quantity of any of the arsenics being mix'd with a metal, renders it friable, or destroys its malleability. And hence the refiners dread nothing so much as arsenic in their metals; and it would be advantageous to them, were such a thing to be had, as a menstrum that would absorb, or act on arsenic alone: for then their metals might be readily purified, without flying off, or evaporating; which often occasions great loss, labour, and expence. Arsenics do not dissolve in water, but hang therein after the manner of feathers.

(*k*) Consult *Hoffman's Observ. Phys. Chem.*

(*l*) By bituminous sulphurs we mean such pitchy mineral substances, whether solid or fluid, as are inflammable, soluble in oil, and immiscible with water. Thus a solid bitumen is any hard, brittle, mineral body, fusible by fire, readily inflammable, and soluble in oil; thus appearing to resemble pitch, as the liquid bitumens resemble tar; though their colours and degrees of consistence may be various.

(*m*) Some naturalists, as Dr. Woodward, &c. extend bitumens into a general class, an-

swering, in great measure, to the class of sulphurs. Accordingly, they subdivide them into liquid, or naphtha, including petrol and oleum terra; and solid, under which they range amber, jet, bitumen, asphaltum properly so called, and coal.

(*n*) It is frequently confounded with naphtha, tho' it be very different therefrom; as being thinner, more penetrating, and less inflammable.

It is found in several countries, particularly the duchy of *Modena* in *Italy*; and is of several colours, red, yellow, green, white, &c. which diversity is supposed to arise from the different situation of the rock with respect to the sun: thus the white, which is reputed the best, is said to proceed from that side most exposed to the sun's rays; then the red, then yellow, &c.

'Tis used for burning in lamps, and externally in paralytic disorders, &c.

(*o*) *Naphtha* is a ruddy kind of oil, exuding out of a rocky or stony earth; exceedingly inflammable, so as to catch fire even from a candle held at a distance; and so combustible as to continue burning under water. 'Tis found in several parts of *Chaldea*, particularly where the ancient *Babylon* stood; as also in *France*, and some other countries of *Europe*. That of *France* is like melted pitch, very black, and of a rank smell.

and it burns vehemently in the fire. The same being further dried, and concocted by the heat of the sun, or fire, or even by length of time, becomes harder than pitch, grows shining and ponderous, but is still fusible by fire, miscible with any unctuous body, and inflammable; in which state it is denominated Jews-pitch, or *Bitumen Judaicum* (p).

Jewish pitch.
Pissaspaltum.

4. *Pissaspaltum*, by the very sound of the name shews it of an intermediate kind between pitch and bitumen; being of a black colour, earthy and strong scented, and only seeming to differ in degree from the former: it is probably generated either naturally, or artificially, by a different mixture of fat bodies with melted bitumen (q).

5. The same, when advanced so far towards perfection by nature, as to become black, hard, earthy, flaky, smooth, strong scented, and glossy, seems to form that stone usually called jet, or *Thracium Nicandri* (r).

Jet.
Thracium Nicandri.

6. If fat bituminous substances mix with stony glebes, or sometimes perhaps with the *Scoria* of metals, they harden together, and thus form a solid, scaly, black, fat, flaky, inflammable matter, called *Litbantbrax* or pit-coal (s); which seems also to belong to this head.

Coal.
Litbantbrax.

7. *Amber*, called also *Carabe*, *Succinum* and *Electrum*, comes likewise under this head; as seeming to be the produce of a bituminous sulphur. It burns, and at the same time melts in the fire. It consists of a liquid, acid salt, which hardens into solid glebes; and of a fossil oil, nearly resembling petrol. Its colour is either white, citron, yellow, black, or red (t).

Amber.

8. The

(p) The *asphaltum* is of a shining black colour, and so like *Stockholm* pitch, that were it not for the rank smell of that pitch, and the superior hardness of the *bitumen*, there would be no distinguishing them.

'Tis usual to sophisticate the *asphaltum*, by mixing pitch with it, whence the *pissaspaltum* is made; which the coarseness of the black colour, and the fetid smell easily discover.

There is another *asphaltum*, which is a mineral stone found in the valley of *Sydim*, near the ancient *Babylon*; and lately also in the county of *Neuchâtel*, the oil whereof makes an excellent cement; and hence is supposed to be the mortar so much celebrated among the ancients, wherewith the walls of *Babylon* were laid.

(q) *Pissaspaltum*, or *Jews-pitch*, is a sort of bitumen, found on the surface of the lake *Asphaltos*, or dead sea, in *Judaea*; which tho' at first liquid, yet hardens in the air, and is brought to us in a firm consistent mass. So that it may rather be rank'd among the solid than the liquid sulphurs.

(r) *Jet*, otherwise called black amber, is a bituminous, dry, hard, black, smooth, glossy, uniform substance; capable of a good polish, burning almost like pitch, and appearing to be a fine kind of pit-coal. It is

found in many countries of *Europe*, as *Germany*, *France*, *Sweden*, *Ireland*, and *England*, particularly in *Lancashire*, where they make boxes, salt-sellers, &c. of it.

(s) Pit-coal may be esteem'd a coarser kind of jet, being mix'd with a large proportion of earth; as appears by the ashes it leaves behind upon burning. It might be of great service, if an easy and cheap way were known of extracting the oil out of common coal.

(t) *Amber* is chiefly found in the *Baltic-Sea*, and along the coasts of *Prussia*. Naturalists have been extremely in the dark about its origin and formation; some have maintain'd it an animal substance; others take it for a resinous juice, oozing from poplars and firs, frequent on those coasts, and discharged into the sea; where undergoing some alteration, it is thrown on shore in this form: but the generality of authors contend for its being a bitumen, which trickling into the sea from some subterraneous sources, and there mixing with the vitriolic salts, which abound in those parts, it becomes congeal'd, or fixed thereby; the result of which congelation is amber. But good amber is frequently found in digging far from any sea-coast, which seems to make it a fossil.

There are several indications which discover where this amber is to be found: the surface of

8. The *Oleum terræ*, produced in *India* and described by *Neubovius*, is scarce *Oleum terræ*. imported into *Europe*, but kept by the princes of *Asia* for their own uses. Whether therefore this be a species of *Petrol*, or *Naphtha*, I will not determine: but that which is brought hither, and sold under this denomination is obtained from the expressed oil of coco-nut mix'd with medicated earths, as I have been informed from a very good hand. And consequently it ought rather to be rank'd in the class of vegetables. Is not that called *Barbadoes-tar*, *Barbadoes tar*. prepared after the same manner?

of the earth is there cover'd with a soft scaly stone; and vitriol, in particular, abounds there. Amber assumes all figures under ground, as of a pear, an almond, a pea, &c. among others there have been found letters very well form'd, and even *Hebrew* and *Arabic* characters; within some pieces of amber have likewise been found leaves, insects, &c. this, with some, passes as a proof that amber was originally in a fluid state; tho' others rather account for it, by supposing the amber to have been exposed to the heat of the sun, and by that means soften'd, so as to receive the leaves, insects, &c. which opinion is countenanced by this, that those heterogeneous matters are seldom found in the centre of the piece, but near the surface.

The amber which we commonly meet with is a bituminous, hard, dry, transparent, toughish, tho' brittle substance, either of a white, yellow, or dusky brown colour, of an acidish, bituminous, and somewhat styptic taste, and, when warm, of a peculiar fragrant tartish smell, resembling that of a moldy lemon. It is electrical, and seems to have given that name to other substances which attract light bodies. When its natural history, nature, and pro-

Of perties, come to be well consider'd, it pretty clearly appears to be originally a bituminous mineral juice, form'd in the earth, being at first in a liquid state, but afterwards condensed, or harden'd. In some parts of *France*, and particularly in *Provence*, it is dug from mountains; and so it is in *Italy* and *Sicily*, tho' this is only a coarse dark-coloured and indifferent sort. The best is found in *Prussia*. *Hartman*, who has given a good history of amber, judges from phenomena that all *Prussia* is upon a bed of bitumen, or matrix of amber, which ouzes out large quantities of this mineral, sometimes nearly up to the earth's surface, especially about the sea-coasts. But intermix'd with the amber are found a kind of mineral trees, differing in their texture from the common vegetable kind, as consisting of flat plates lying upon one another; and from these *Hartman* presumes the amber proceeds; it being seldom found without them, and is sometimes contained in them.

Its uses.

Its mechanical uses are seen in cabinets, toys, utensils, and the better kind of varnishing. In medicine 'tis esteem'd good against nervous disorders, convulsions, the *fluor albus*, &c.

A P P E N D I X.

Natural history of ambergrease.

Ambergrease seems also referable to this class of bituminous sulphurs, tho' there are various opinions as to its origin; some take it for the excrement of a bird, which being dissolv'd by the sun's heat, and wash'd off the shore by the waves, is swallow'd by whales, who return it in the condition we find it: others imagine it a sort of gum, which distilling from trees, drops into the sea, where it congeals into ambergrease. Others suppose it a sort of spongy earth, which the working of the sea washes off the rocks; where, being lighter than water, it floats; others contend for its being form'd from honey-combs, which fall into the sea from the rocks, where the bees had form'd their nests; several persons

having seen pieces, half ambergrease, half honey-comb. Lastly, others will have it a sort of a bituminous juice, which springs out of the bottom of the sea, as naphtha does out of some springs, and there thickens and hardens.

Ambergrease is found on the sea-coasts; particularly those of *Africa*, from the *Cape of Good Hope* to the *Red-Sea*, and the adjacent islands; in some places of the *Mediterranean*, and the island of *Bermudas*. It is a light, solid, grey, tallow-like, marbled substance. 'Tis most probably a kind of bitumen, flowing out of the earth, in a liquid form, into the sea; where it hardens, and floats on the surface, or is thrown upon the shores. In the middle of the lumps, which are sometimes very large,

we

Of STONES.

*Stones, their
character.*

1. "Stone is a hard fossil body, not ductile, but brittle, fix'd in the fire, and not easily fusible thereby, nor dissolvable in water (u)."—By which marks, stones are accurately distinguished from metals, salts, and sulphurs (x). Stones seem

we frequently find stones, shells, bones, &c. It melts over the fire into a kind of yellow rosin. It is inflammable, and soluble in spirit of wine; only leaving a black bituminous matter behind, which the spirit will not take up.

Its uses.

'Tis much used by the perfumers, as giving a rich sweet odour in mixture, especially with musk. In medicine it is esteemed a high cordial. The best is that which is clean, of a light grey colour, a strong scent, and, when prick'd with a hot needle, ouzes out an odorous liquor.

(u) Nor in oil.

Natural history of gems in general.

(x) Stones are distinguish'd from metals by being friable; which is a property that even diamonds themselves are not without: they are distinguish'd from salts by not dissolving in water; and from sulphurs by not fusing in the fire.

Precious stones, called also gems or jewels, are hard, transparent, and of a beautiful colour, or water.

The diamond, or adamant, is the hardest, and most transparent of all bodies; it may be added, the most simple and homogeneous too: so that the diamond seems to be that among stones, which gold is among metals. The pseudo diamond is sufficiently pellucid, compact, and weighty; but not so hard, nor capable of the lustre and polish of the true diamond.

Some naturalists make more minute divisions of stones: Bishop Wilkins considering stones in respect of their value, makes an intermediate kind between vulgar and precious, viz. middle-priz'd. He likewise divides precious stones into more and less transparent. The less transparent he distinguishes by their colours: into red, as the sardin and cornelian; pale flesh colour, like that of a man's nail, as the onyx; bluish, as the turquoise; pale purple, as the chalcedony; and those of various colours, as opal and cat's-eye.

The more transparent he distinguishes into such as are colourless, as the diamond and white saphir; and coloured, which are either red, as the ruby, carbuncle, and granate;

yellow, as the chrysolite and topaz; green, as the emerald, smaragd and beryl; bluish, as the saphir; and purple or violaceous, as the amethyst and hyacinth.

Dr. Woodward chusing to consider stones, not in respect of value, which is arbitrary and extrinsic, but of something that belongs to themselves, divides them into those found in larger masses, and those in lesser masses; which latter he subdivides into such as do not exceed marble in hardness, and such as do exceed it. These last make the class of precious stones in the other divisions. He divides them somewhat more precisely into opaque, semi-opaque, and transparent. (1) The opaque are either of one colour, as the turquoise; or of various colours, as lazuli and jasper. (2) Semi opaque, either have their colours permanent, as the agate, chalcedony, onyx, sardonix, cornelian, and beryl: or their colours vary, according to the position of the light, as the oculus cati, and opal. (3) Transparent stones are either with colours; as the topaz and jacinth, yellow, or partaking thereof; granate, ruby, and amethyst, red; saphir, water-saphir, and aquamarine, blue; and emerald or chrysolite, green, or partaking thereof; or without colours, as the crystal, pseudo-diamond, white saphire, and diamond.

Dr. Stare seems to make the specific gravity of stones their adequate standard; as our author does in metals. He speaks of several bodies which appear, in all respects, like stones, and are commonly rank'd as such; but which, by the hydrostatical ballance, are found to want of the necessary weight; such, e. gr. is chalk, and various other bodies taken for granted to be stones; some of which are nearer earths than stones, and others nothing but earth, sulphur, and metal. Of the former many fall short of the standard of stone, and others exceed it: whereas true stones, says he, though differing much in hardness, whether pebbles, flints, petrified waters, &c. answer the same standard of specific gravity as a diamond does: which is to that of water as $2\frac{1}{2}$ to 1.

The hydrostatical ballance, says Mr. Boyle, is of prime use in discerning genuine gems from counterfeit, which too often pass for true, to the prejudice of physicians and their patients,

seem commodiously reducible to three kinds; viz. transparent, semi-transparent, and opaque.

(1.) Of

patients, and the loss of lapidaries; for, as there are, perhaps, no qualities of bodies more essential than their ponderosity, so there is scarce any, wherein impostors find more difficulty to make a notable alteration, without being discovered. In several cases, indeed, 'tis not very difficult to alter the specific weight of a particular body; yet it may be impracticable to make any considerable alterations in the quality, unless by such additions and operations as will cause a sensible alteration in some other qualities, and so subject the cheat to a discovery. He proceeds to give instances of discoveries he himself had made by this means*.

Many authors, not only among the ancients, but the moderns, are full of the virtues and medicinal properties of precious stones; but their reputation, in this respect, is now not a little fallen. Yet, as the fragments of such stones are still preserved by the physicians, in some of the most celebrated compositions; as there are certain chemical preparations made of them; and as several persons of the greatest candour and experience, have related some considerable effects of certain gems, on their own particular observations; and lastly, as it is no way improbable that some of the softer stones may have some considerable operations on the human body: it might be imprudent indiscriminately to exclude them from any medicinal virtue at all. When much the greatest part of their traditionary qualities are set aside as fabulous, there will still remain some, on as real, and well-warranted a footing, as many of our other medicines.

On such considerations the excellent Mr. Boyle was induced to give us that extraordinary piece of the *origin and virtues of gems*; the purport whereof is to shew, "That such stones were originally in a fluid state, or are made up of such substances as were formerly fluid; and that many of their general virtues are probably derived from the mixture of metalline, and other mineral substances usually incorporated with them; while the great variety, and the particular efficacy of their virtues arise from some happy concurrent substances of that commixture; e. gr. the peculiar nature of the impregnating liquor, the proportion wherein it is mixed with the petrescent juice, and the like."

To support this hypothesis of the virtues of gems, he shews that several of them are not

simple concretions of any petrescent liquors, but consist also of other mineral adventitious parts; which he argues from the separableness of such substances in some stones; the specific gravity in others; and the different tinctures to be met with in gems of the same species, as rubies, sapphires, granats, and even diamonds, of which some are yellow, some of other colours, and some green, almost like emeralds. There may therefore be in some gems numberless adventitious corpuscles; but there is reason to think that some of these corpuscles may be endued with several properties and medicinal virtues: there is a great difference among these impregnating particles, and probably a greater variety than is known by us; and lastly, many gems are richly impregnated with these particles: why, then, may they not exert some power? This is the substance of what is directly alledged in behalf of gems.

The stress of what is objected against them is this, "The mineral substances they contain are so closely locked up, that they can communicate nothing to the body, and so can have no medicinal operation; being unquerable by so small a heat as that of the stomach, and other parts of the body."

Which objection might be plausible enough, to prevent the ascribing any medicinal virtues to them *a priori*; but can conclude nothing against what is warranted by so many facts, and observations; especially, when there are several particulars, that obviate this objection. For a vigorous load-stone, tho' frequently harder than many gems, is known to emit copious effluvia; and there are many which have been found to have a manifest and inconvenient operation on the body, by being wore in the pocket, or long held in the hand. Mr. Boyle has found many transparent pebbles, which when cut would resemble diamonds, that might be immediately brought to emit copious and strong-scented steams. And if electrical attractions be owing to the effluvia of bodies heated by rubbing; very slight alterations may suffice to procure expirations from transparent gems, many of which are electrical, and even the hardest of all, viz. diamonds, one of which Mr. Boyle kept by him, which upon a little friction would attract very vigorously.

To that part of the objection, which pretends gems not to be digestable by the heat of the stomach, it may be replied, that we

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do

* Boyle Abr. Vol. II. p. 328, 329.

(1.) Of TRANSPARENT STONES.

Transparent
gems.
Affinity with
glass.

2. *Transparent Stones*, are properly enough called *Gems*, so as to constitute a *Genus*; these nearly resemble glass, in many respects; tho' they surpass it in hardness, solidity, simplicity, and difficulty of fusion by the fire. They seem composed of a fine perfect kind of salt and earth intimately mixed; as glass is of salt and ashes fused by fire (*y*). Those gems which are perfectly transparent, without any mixture of colour, come the nearest to glass.

Crystal.

3. *Crystal*, seems entitled to the first place in this class; being a white, pure, bright stone, capable of cutting glass, not easily fusible by fire, formed by a certain direction and concurrence of *Radii*, and *Strata* (*z*).

Diamond.

4. The genuine diamond is a most pure, hard, solid, transparent, glittering, precious stone; apparently the most perfect of all the gems of the crystal kind;

do not know how far the digestion of things in the stomach is owing to heat. Nor is it proved that such materials can have no operation on the body, without being digested, *i. e.* in passing through it without undergoing any sensible change of bulk, figure, &c. as gems, when swallowed, are supposed to do. For some chemists make a kind of bullets of regulus of antimony, which they call *pilula perpetua*, because when they have performed their operation in the body, and are discharged with the excrements, they may be used again and again for the same purpose. Nor do we know what analogy there may be between some juices in the body, and those mineral parts which impregnate gems: for though *oculus mundi* be reckoned among the rare gems, yet if one of the best sort be for a while kept in common water, it will receive an alteration obvious to the eye. Add, that Mr. Boyle has, without heat, obtained a manifest tincture from several hard bodies, and even from a transparent sort of gems. And whether some juices of the body, assisted by the natural heat thereof, may not serve for menstrua to some gems, we will not say: but even the natural heat of the stomach, nay, perhaps, of the external parts of the body, may be able, though not to digest precious stones, yet to fetch out some of their virtues: for 'tis certain, it makes a sensible alteration in the hardest sort of them: witness a diamond of Mr. Boyle's, which might have its electric faculty excited without rubbing, only by a languid degree of adventitious heat; and another, which, by means of water made a little more than luke-warm, might be brought to shine in the dark.

Lastly, if it be objected, that 'tis not likely gems should part with any effluvia, or por-

tions of themselves, as they lose none of their weight; it may be answered, that the antimonial glass and cup communicate a strong emetic quality to wine and other liquors, without suffering any sensible diminution of weight*.

(*y*) This resemblance should not be much depended upon, as a proof that gems are composed by nature after the manner of glass, which is an artificial thing, that differs in several respects from gems; some of which appear plainly flaky, feel soft like amber betwixt the teeth, with a kind of toughness, and both pulverize and endure the fire, in a different manner from glass.

(*z*) Rock-crystal is a soft transparent gem, somewhat resembling ice; it seems to shoot or grow in a particular figure, after the manner of a salt; being hexagonal in the middle, and pyramidal at both ends. 'Tis easily reduced to powder, especially after calcination, and quenching in water or vinegar; and thus may be made the basis of artificial gems. But the art of making them, in this manner, to perfection, is not generally known; though we have seen some, little inferior to natural stones, even the diamond itself, except in hardness.

Island crystal is a peculiar sort, consisting of crystalline plates, joined together, which may be easily separated. All objects seen through this crystal appear double, on account of the double refraction of the rays of light†.

A third kind of crystal is that mentioned by Dr. Lister in the Philosophical Transactions; having a great smoothness, transparency and lustre, nearly resembling the diamond. It is found in different parts of England.

* See Boyle Abr. Vol. III. p. 99. & seq.

† See M. Hugen's, and Sir J. Newton's Optics.

kind; excelling all bodies in the vividity of its reflecting of light; and enduring the fiercest fire for a very long time without melting (a).

5. Bastard-diamonds, or *Pseudo-Adamantes*, of the purer kind, approach *Bastard diamond.* the true diamond; but are softer, less solid and transparent than it.

6. The *white saphir* is akin to the diamond. The same may be said of *White saphir.* the *oriental amethyst*, which is colourless, either by nature, or art. And the *Amethyst.* topaz, and chrysolite, when discharged of their colour, approach to the *Topaz.* nature of diamond (b). The true *astroites*, which in the sun-shine darts *Chrysolite.* rays of light from a certain fix'd point, belongs also to the transparent kind. *Astroites.* In all these the value rises in proportion to their degree of hardness, solidity *Value where- on depends.* and transparency.

7. Those gems which, tho' transparent, are tinged with some beautiful colour, approach to the nature of the former, only with the addition of some metalline pigment, or other fix'd fossil body; which is intimately mixed and incorporated with them in their first formation: as may be gathered from the resemblance of colours, as well as from the manner of making artificial gems.

8. To this class belong the amethyst, beryl, carbuncle, chrysolite, granate, hyacinth, opal, ruby, saphir, emerald, topaz; likewise all colour'd crystals. And the value of these also depends upon their degree of hardness, solidity, purity, simplicity, and brightness of colour. (c). *Value.*

2.

(a) The diamond is often blemish'd, with white, yellow, or black spots, which greatly diminish the value; whence various ways have been tried to get them out. They are of different colours, white, yellowish, bluish, reddish, &c. Diamonds consist of crystal plates or *laminae*, somewhat in the nature of *Iceland crystal*; so that skilful lapidaries can separate them with the edge of a knife*. They are not calcinable by common fire; nor in the focus of a burning-glass, if only the plain flat surfaces are thus exposed to the sun's rays; but if the edges of the plates are turned to the rays, they split, separate, and run into a kind of glass, which has not the lustre of a diamond. They are chiefly found in the *East-Indies* and *Brazil*. The manner of making artificial diamonds at *Paris* deserves to be enquired into.

(b) The saphir comes nearest to the diamond in hardness, splendor, and transparency. It is of two kinds, the one pale, called the female saphir, the other blue, or sky-coloured, with a reddish, or purple refraction, called the male. Saphires are brought from different parts of the *East-Indies*, and are thence called *Oriental saphires*; others are found in *Silesia* and *Bohemia*; and are called *Occidental*. The colour of the blue saphires may be discharged by fire, so as to leave the stone like a diamond.

A short account of the more curious transparent-coloured gems.

(c) The *ruby* is a bright, transparent, ruddy gem, of considerable hardness. It is of four kinds, differing in degree of redness; viz. (1) the true ruby, or carbuncle; (2) the *balasus*, having but a faint redness; (3) the *rubicullus*, of a degree of redness betwixt the former two; and (4) the *sponaliscus*, which is softer, and less resplendent than the true ruby. The best are found in the island *Ceylon*. Some pretend to have extracted tinctures from them; though we apprehend the proofs are not clear and direct.

The *emerald* is a beautifully green, transparent, glittering gem, but considerably brittle, so as sometimes to crack spontaneously; which has given occasion to several conceits. It is either *oriental*, or *occidental*; the oriental is by much the best. The other, which comes from *Peru*, has neither the same lustre, nor clearness. It is remarkable, that the powder of this gem, being thrown upon a clear fire, yields a subtle blue flame, and loses its colour; whence one might suspect the stone to be tinged with copper, or a fine metallic sulphur. This may afford a hint for enquiry, whether (1) the coloured gems are not stained with metallic particles? (2) whether they do not consist of two parts, viz. one that is crystalline and fixed, and another that is sulphureous

R 2

* See *Boyle Abr.* Vol. III. p. 144. & seq.

(2.) Of SEMI-TRANSPARENT STONES.

Semi-transparent.

1. Between gems and opaque stones we find an intermediate kind, which may be called semi-transparent; as being of a more compound nature than the former.

Value.

2. The chief among these are the agate, sand, another sort of *Astroites*, the true *Armenian* stone, the toad-stone, the cornelian, chalcedony, heliotrope, or true oriental jasper, true *Lapis Lazuli*, *Lapis Nephriticus*, *Leucophaalmus*, *Melachites*, *Onyx*, *Sardius*, *Sardonix*, *Selenites*, and *Turquois*; which are found different in degree of opacity (*d*). The qualities which give the value to these, are also solidity, hardness, transparency, and beauty of colour.

(3.) Of OPAKE STONES.

Opaque.

1. The other stones are of the opaque kind, as the eagle-stone, alabaster, *Asbestos*, *Belemnites*, *Gypsum*, *Hematites*, jasper, jews-stone, touch-stone, load-stone, marble, whether white, ash-coloured, yellow, brown, or black, porphire both red and green, *Ophites*, *Osteocolla*, pumice, lime-stone, whet-stone, mill-stone, flint, *Lapis Specularis*, emery, talc and tripoli. Among which

reous and volatile; and (3) whether the colour'd gems may not have some medicinal virtue, different from their absorbing quality?

The *amethyst* is a transparent gem, of a violet colour, betwixt red and blue, but not very vivid: this also is somewhat brittle, apt to crack, and receive scratches in the wearing: whence it is not highly prized. Some pretend to extract a tincture from it; but we should remember that certain menstruums will acquire a colour, by standing in the containing glass, without coming in contact with any other sensible body.

The *japan* was the *chrysolithos* of the ancients, being a transparent gem, of a shining gold-colour; the *oriental* are very hard, and of a beautiful colour, but the *European* are foulish, and soft like crystal.

The *opal* is a beautiful gem, exhibiting a great variety of colours, according to the different refrangibility of the rays of light; and thus besides white and black, it appears either blue, purple, green, yellow, or red. The best opals come from *India*, the ordinary sort from *Egypt*, *Hungary*, *Denmark*, &c. They are found to grow in a soft stone, marked with blackish lines.

The *hyacinth*, or *jacinth*, is a yellowish-red gem, differing in degrees of colour; some being red as cinnabar, others the colour of saffron, and others of yellow amber, &c. which are less esteemed. The *occidental* are better than those of *Silesia*, *Bohemia*, or *France*.

The *chrysolite* is a green-coloured gem, fainter than the emerald, and with a cast of yellow, so as sometimes to appear reddish. It is so soft, that it yields to the file.

But for a further account of gems, see *de Boot*, *Mr. Boyle*, and *Dr. Woodward*.

A short account of the more curious semi-transparent stones.

(*d*) The *Armenian* stone is of a blue colour, somewhat opaque, brittle, speckled, or mottled, with blackish and gold-coloured spots, like the *lapis lazuli*, which differs little from it; and they are often found together in the same matrix, and used indiscriminately for each other. The painters employ it as a fine blue.

The *lapis lazuli*, or azure stone, is an almost opaque, hard, blue stone, full of veins, and spots of gold and silver. It is of two sorts, *oriental* or *occidental*; the first is the finest, and affords the ultramarine, which never changes its colour, whereas the *German* sort is apt to turn green in painting. The best is that of a deep blue colour, speckled with gold, hard to break, and capable of enduring the fire without alteration.

The *onyx* among the jewellers is the *Arabian* sardonix, an opaque stone, wherein a black, or dark blue ground, is encompassed by a white circle. There is also a transparent *onyx*, resembling the colour of a man's nail; from whence the name appears to proceed.

which there is a diversity of nature, as some are more disposed to turn to glafs, and others to a very fixed Calx in the fire (c).

Of

Of the origin and growth of stones.

(c) The origin of stones is a point of curious enquiry, and has accordingly been prosecuted by some of our later naturalists. *Boyle, Tournesfort, and Geoffroy*, have distinguished themselves in this research.

M. *Tournesfort* deduces stones, and other of the fossil tribe, *ab ovo*. Nature, according to him, observes one general law in the production of plants, stones, and metals, which all equally arise from their several seeds, and grow alike. This sentiment indeed is not quite new: *Pliny* assures us that *Mutianus* and *Theophrastus* maintained that stones produced stones. But M. *Tournesfort* sets the system in a new light, and supports it by arguments they were strangers to. In the walls of the labyrinth of *Crete*, which are of living rock, a great number of names have been cut by persons who have visited the same; which names, tho' originally dented, or *in creux*, are now found in basso-relievo, standing out one fourth of an inch from the face of the rock. Now this, he argues, could not otherwise happen than by supposing the dents gradually filled up with some matter oozing out of the rock, and which even oozed more plentifully than was necessary for filling the cavity. This matter, therefore, must have come from the body of the stone, and have consolidated, or healed up the wound made by the knife or chissel, as the callus formed on a fractured bone by the extravasated nutritious juice of the bone fills up the fracture, and rises beyond the surface of the bone. The like is observed in the barks of trees, cut in the same manner. Lastly, the like consolidations were shewn by M. *Tournesfort* to the royal academy, in other stones, as the *attites*, or eagle's stone, and some others fresh dug up. From the whole he concludes, that stones grow in the quarry; that, of consequence they are fed; and that the same juice which feeds them, serves to rejoin their parts when broken; and, in a word, that they are organized, and draw their nutritious juice from the earth, through their surface, which filters it, and serves as a sort of bark. The progress and distribution of such juice through all parts of so hard a body, he adds, is difficult to conceive; but not more so than that of the juice of some trees of very hard wood, as that of *Brasil*, called iron-wood, that of ebony, or even coral, which all allow to be a plant.

Having found that some stones grow like plants, the analogy led M. *Tournesfort* to imagine they might be propagated alike; and there are some sorts, whose generation can scarce be accounted for without supposing them to have arose from a sort of seed, *i. e.* from a germ, wherein the organical parts of such stones were contained in little; as those of the largest plants are in their seeds. The *cornua Ammonis*, *lapis Judaicus*, *asprites*, *entrecbi*, toad-stone, crystals, the several species of pyrites, sea-mushrooms, and infinite others, suppose their particular seeds, as much as common mushrooms, truffles, and divers species of moss do, whose seeds were never yet discovered.

The *cornua Ammonis*, for instance, is constantly in form of a volute, and the *lapis Judaicus* of an olive fluted without side: now, whence this uniform structure, unless from a seed containing it in embryo? Who moulded it so accurately; and where are the moulds it was fashioned in? Nothing like them ever was found, even where the stones are in greatest abundance. *Boot*, after numerous enquiries about the regular figure affected by crystals, concludes, it is as natural thereto as that of the leaves and flowers of any plant; and ascribes the whole to an architectonic spirit, and a kind of faculty, which he calls *formatrix*. But is it not better to suppose they have a kind of eggs; and that the juice they derive from the rocks to which they grow, does, as it were, hatch, and extend them to their destined bulk? Lastly, that immense quantity of round pebbles, wherewith the *Crau of Arles* is covered, for seventy miles round, seems to require the same origin; and accordingly, *Fab. de Pierre*, who held that stones arose from seeds, though in a different manner from M. *Tournesfort*, looked on this plain as a convincing proof of his opinion*.

But this doctrine seems, in good measure, obviated by Mr. *Boyle*, who undertakes to prove, that gems, in particular, were originally in a state of fluidity. This he argues from a great number of considerations: as (1) The transparency of those stones; which is a quality depending on such an order of the constituent particles, as cannot well arise without supposing them originally capable of being moved with the smallest impulse, and of giving way to the rays of light. (2) The figure, which in many is determinate, and geometrical,

* *Memoir. de l'Acad. an. 1702.*

Characters of
earth.

Boles.

To this last class we subjoin earths "which are native fossils, usually somewhat unctuous, so that when mixed up with water, they may be wrought into a paste, and hence denominated boles, but not soluble either by water or fire." Such are *Argill*, or white clay, *Axungia Terra*, or *Axungia Luna*, *Cimolia*,

geometrical, bearing a near analogy to the crystals which we see arise from the dissolutions of nitre, alum, vitriol, or the like in water.

(3) The texture, which nearly resembles that of several coagulations of bodies formerly fluid. Thus, dissolved salts, silver, &c. are found to coagulate into masses of a thin flaky texture; and the like texture. Mr. Boyle has observed in divers gems, which, even to the naked eye, have appeared full of parallel commissures, made by the contiguous edges of little thin plates of stone, lying one over another, like the leaves of a book a little opened. Add, that the microscope discovers a parallel structure, even in the most compact of all, the diamond; whence proceeds what they call the grain of those stones, and the difficulty, nay impossibility of cleaving them against this grain without breaking. (4) The colours of many of them appearing to be adventitious, and derived from some tinging mineral, which could not be so well imparted to them, unless in a state of fluidity. Accordingly, many gems have been deprived of their colour, by continuing long in the fire; and the experienced *Boot* affirms, that this will hold of all gems, except the *Bohemian* granat. Hence it is that the fire alters the colours of many gems, after the same manner as it does those of divers fossil pigments. Add, that some gems, which the lapidaries, without scruple, affirm to be of the class of rubies, sapphires, &c. are either colourless, or have different colours from those which usually belong to them. (5) From heterogeneous matters being frequently found inclosed in solid gems; particularly flies, straws, grasshoppers, drops of liquor, &c.

The fluid state of stones then seems almost incontestible: and accordingly M. *Tournefort* himself is forced to allow of it in some cases. He even makes use of the notion, to account for the formation of divers uniformly figured stones, as the species of *pechinites*, *conchites*, *mytilites*, *ostracites*, *nautilites*, *echinites*, &c. The fluid seeds of these stones he supposes to have been received into the cavities of their corresponding shells, the *pecken*, *concha*, *mytilus*, *ostrea*, *nautilus*, *echinus*, &c. and thus moulded into the figures wherein we see them. Nor

does Mr. Boyle himself consider the liquidity of stones as inconsistent with their arising from a semen: *If there be a seminal and plastic power*, says he, *in stones, why may it not be harboured in liquid principles; when we see that the seed of animals, from which arise hard solid bones, is at first a fluid?* In reality, a seed may be contained in a fluid vehicle; which we suppose is the case in animals: but the proper feed, or stamen itself, must inevitably be a solid, according to the notion of a seed, which is nothing but a little organized body, wherein all the parts of the future production are contained in small; the production itself is only the seed enlarged, so as to shew its several parts to the eye. But fluidity is inconsistent with any such organization.

Monf. *Geoffroy* supposes, that earth alone, without any other mixture of salts, sulphurs, or the like, is the basis of stones, and the only matter necessary to their formation; i. e. the earth may be mixed with salts and sulphurs, as we find it is in many stones, but this is not absolutely required; 'tis only by accident that it does happen, and there are other stones without any at all; as the common stones of quarries, white flints, &c.

Earth, according to this philosopher, consists of two kinds of primitive parts; the one in very thin equable plates, the other in all kinds of irregular figures. When the parts of the first kind meet together in a sufficient quantity, the regularity and equality of their figures, determines them to range themselves in a regular and similar manner, and thus to form a homogeneous compound, which, at the same time, must be very hard, on account of the immediate contact of its parts, and transparent, by reason of their regular disposition, which leaves a free passage for the light every way: and this is *crystal*; which accordingly is looked upon as the most simple, pure, and homogeneous of all precious stones. As to the terrestrial parts of the second kind, they can only form opaque and softer assemblages. Crystals, therefore, being alone formed of the parts of the first kind, all other stones must arise from a mixture of both. Those of the first unite and bind together those of the second;

Cimolia, fullers-earth, boles white and *Armenian*; the *Cbian*, *Eretrian*, *Lemnian* and *Maltese* earths; ruddle; *Samian*, *Selinusian*, *Tocovian*, and all the seal'd earths. But there are others of a dryer, and leaner kind; as chalk, ochre, and marl (f).

second; (which without them would be no more than sand or dust) and give them hardness and consistence.

To explain this, he observes, that water is a proper vehicle for the conveyance of the terrestrial parts of the first kind; as petrifying waters line the pipes they run thro', or case over other bodies laid in them with a crust of stone. Strictly speaking, the water does not dissolve these earthy parts: it only keeps them in fusion, as it does the juice of many sorts of plants. From this resemblance, he calls these parts the *crystalline*, or *stony juice*.

This juice is more heavy and fixed than water; and consequently does not evaporate with it, but is left behind; and thus is the formation of crystal, perfectly like that of the crystals of salts. For these crystals only arise with those regular figures they affect, as when a water impregnated with salts is slowly evaporated in a moist place: the evaporation of the water is necessary, that it may not keep the salts too far asunder; and the slowness of the evaporation, that the salts may have time to take that arrangement, which agrees best with their respective figures. The application of this to rock-crystal is obvious: there needs but to conceive that a water, charged with a quantity of crystalline juice, had insinuated itself thro' the clefts of some rock, and fallen to the bottom of a grott, where the aqueous part gradually evaporated.

It must be considered, that this crystalline juice is not equally diffused in all parts of the earth, so that rock-crystal would not arise in all places, even setting aside the necessity of other concurrent circumstances, which do not often meet. If the water impregnated with this crystalline juice happen to penetrate a mass of earth, which is the most usual case, it will connect, or bind together the parts thereof, by means of this juice; and afterwards, in proportion as the watery part evaporates, the compound will grow harder, and at last become stone. Add, that it will approach nearer to the nature of crystal, i. e. will be more hard and transparent, according as the quantity of that juice is greater; and at the same time of a finer grain, according as the molecules of the earth are smaller and more homogeneous. Of this kind are marbles and alabasters, in some of which one may

discern veins or threads, as transparent as if they were wholly crystal. The stones most opposite hereto, and most imperfect, are chalk and boles; which are little else but earth ill bound together, with a very small quantity of crystalline juice; which leaves them still friable. 'Tis easy to imagine infinite degrees between these.

The particular circumstances which attend the formation of stones, vary the effect of these general principles divers ways. For instance, if a portion of this crystalline juice, diluted in water, chance to be surrounded with earth, and the juice be not in quantity sufficient to petrify the whole earth, as fast as the water evaporates; there will arise a mass, partly crystalline and transparent, and partly opaque, dissimilar, and earthy. If the same crystalline juice be in the middle of the mass, only the middle will be transparent, and covered over with an opaque crust. Such are agats, &c. On the contrary, if the crystalline juice be, by any cause whatever, driven from the centre toward the circumference, there will be a pure earth in the middle of a stone, tolerably transparent: such are several flints, &c.

Natural history of sand.

(f) Sands are properly little crystals, or semi-transparent pebbles; that by the addition of a fixed alkaline salt are fusible and convertible into glass; and therefore to be comprehended under semi-opaque stones.

'Tis the character of sand to be indissoluble, and retain its figure in water, and not to be calcinable by fire, as flint and other stones are; and yet it agrees with flint and some metals in striking fire with steel; though this only holds of the proper or mountain sand; a great part of what commonly passes for sand, being not originally such, but only a dust or powder, ground or broke off other stones by attrition; and called sand from the smallness, little cohesion, and dryness of the grains. Dr. Lister observes, that the real sand is of a constant figure, and always preserves its original magnitude; and from the great hardness, durability, and unalterable quality of this fossil above all others, together with some other considerations, concludes it to have anciently been the exterior, and most general cover of the surface of the whole earth. He divides the *English* sands into two classes: the first, *sharp* or *rag-sand*, consisting of small trans-

Of SEMI-METALS.

*Semi-metals,
their character.*

1. The seventh class of fossils, comprehends those which either contain the known, true metals, or else bodies so near akin thereto, that they may almost pass

transparent pebbles, naturally found on the mountains, and not calcinable; and these he further divides into *fine* and *coarse*; subdividing each according to their colours, into white, grey, reddish, brown, &c. The second, *soft* or *smooth*; which he subdivides into one with *flat* particles, broke from lime-stones; another with *silver-like* particles, and a third with *gold-like* particles*.

It seems to be the office of sand to make unctuous earths fertile, and fit to support vegetables, &c. For earth alone, we find, is liable to coalesce, and gather into a hard, coherent mass, as appears in clay; and being thus imbedded, and as it were glued together, is no way disposed to nourish vegetables. But if such earth be mixed with sand, its pores are thereby kept open, and the earth itself loose, so as thus to give room for the juices to ascend, and for plants to be nourished thereby. A vegetable planted only either in sand, or in a fat glebe, or in earth, receives little growth or increase; but a mixture of both renders the mass fertile. In effect, earth is in some measure made organical by means of sand; pores and spaces something analogous to vessels, being hereby maintained, by which the juices may be conveyed, prepared, digested, circulated, and at length discharged; as will hereafter be shewn in treating of vegetables.

History of earths.

Earth is an insipid, opaque, fossil body, indissoluble by fire, water or air, more fusible than stone, still friable, and usually somewhat unctuous. Earths are divided into *simple* or *immutable*, and *compound*; tho' perhaps there is no such thing as a strictly simple earth; Mr. Boyle having observed that neither nature nor art appears to afford any elementary earth; at least some which seem of the simplest sort are found upon examination to have qualities not ascribed to pure earth†.

To the first kind are reducible *chalk*, which is the simplest and driest of all *earths*, as having no discernible fatness at all, and appears to be dense and brittle, readily stains the fingers, and sticks to the tongue without any astringency. Different kinds of earth come under the denomination of chalk; among which those used in physic are the white chalk and red oker. The best white chalk called *terra Cretica*, was

formerly brought from the island of *Crete*; but is now found in several other countries. It drinks up, and ferments with acids; and is therefore successfully used in acidities of the first passages, and particularly in the *heart-burn*; it softens the acrimony of the fluids, and checks the violent motion of the bile, and consequently proves of service in some kinds of *fluxes*——Under this species of earths, *pumice*, *rotten stone*, &c. may be comprehended.

The second, or the compound kind of earths take in the different *boles*, as the *red*, *white*, and *brown*; most *clays*; especially all the fat ones, which are wrought up and dried into potter's ware; *fullers earth*; the several kinds of medicinal earths, and some marls.

Bole is a ponderous different-coloured earth, fatter than marl, but less fat than clay, somewhat soluble in the mouth, of a rough taste, and stains the fingers. Only the *Armenian* and common bole are employed for medicinal purposes; being accounted astringents and softeners of acrimony, when internally given; and drying and astringent in outward application.

Clay is a ponderous, dense, fat, viscid, and slippery earth; and being held for some time in the mouth, leaves an impression on the tongue, something between that of soap and fat. When fresh dug, it may be moulded into any figure, like soft wax; and by fire be changed to a stony hardness. The species of clay are almost numberless; several of which should seem to deserve the title of simple earths; tho' on a strict examen they appear very compound. Thus Mr. Boyle thinks tobacco-pipe clay, by reason of its fixity, whiteness, and insipidity, may with almost as much probability, be accounted elementary, as any other native earth; and yet tobacco-pipes well baked, may sometimes be made to strike fire; and we have frequently found, that two pieces of new tobacco-pipe, being briskly rubbed together, would in a minute or two grow warm, and being immediately smelt to, manifestly afford a rank scent, between sulphureous and bituminous; almost like that which proceeds from pebbles and flints rubbed hard against each other; as if tobacco-pipe clay were not a true earth, but a fine white sand, consisting of grains too small to be distinctly seen.

* See *Phil. Transact.* N^o. 164.

† See *Boyle Abr.* Vol. III. p. 452.

pass for the same; nay, and by good authors are referred thereto. The least compound of these may be properly reduced to three kinds. Semi-metals ^{Species.} composed of a true metal combined with a salt; which are usually known by ^{Vitriols.} the names of *Atramenta Sutoria*; *Chalcantba*; and vitriols. These again are of two kinds: some wherein the ingredient-metal is iron, distinguishable by ^{Atramenta} their green colour; others whose ingredient-metal is copper, remarkable for ^{sutoria.} their beautiful blue colour. For the other metals, it does not appear they undergo any dissolution in mines; as their solvents, being the acid spirits of nitre, or sea-salt, are rarely met with there. Whence we scarce find any such thing as dissolved or concrete juices of gold, silver, mercury, lead or tin, and never in any large quantity. 'Tis true the metalline-part of lead may be dissolved by a weak acid; but then it is scarce reducible into crystals: instead of which, letting go its acid, it immediately turns into powder of cerufs: and the same holds true of tin. ^{Chalcantba.} ^{From iron.} ^{From copper.}

2. All fossil vitriols, therefore, hitherto discovered, consist either of iron or copper. Not but the small fragments or dust of other metals may chance to be mixed with vitriol, when in a state of solution, and thus grow into a mass therewith; but that other metals may equally be dissolved by the same solvent, and intimately united therewith, does not appear.

3. Iron and copper have the same solvent, viz. an acid, which may be separated therefrom by a strong fire; and this acid is known by the name of spirit, or oil of vitriol: the same may also be procured by art, from alum, or collected

seen. The same author observes, that porcellane, or the matter whereof *China* dishes are made, is a pure sort of clay, which yet is sometimes somewhat fusible in a violent fire; and will strike fire with steel, almost like a flint; to which it approaches in specific gravity. And the like has been found to obtain in an imitation of porcellane with a sort of *English* clay*.

Dr. Lister makes clay a genus, almost as extensive as earth itself; dividing clays into two grand classes, under the titles of *pure* and *mix'd*. The former are soft and soluble in the mouth, and have little or no grittiness; and these are subdivided into *greasy*, which include the medicinal earths, or *terra sigillata*, as fuller's earth, yellow, brown, and white; boles, cow-shot clay; and a dark blue clay: *barb* and *dusty*, when dry, as *Creta*, properly so called, or the milk-white clay of the isle of *Wight*; potter's-clay, yellow, blue, and red; and *stony*, when dry, as the several sorts of stone clays, and clunch. — *Mix'd clays* he subdivides into those with *round sand* or *pebble*; as the yellow loam of *Kipworth-Moor*; the red sandy clay near *Rippon*, &c. and those with flat or thin sand, glittering with *mica*; as crouch-white clay,

grey or bluish tobacco-pipe clay, and a red clay in the red sand rock at *Rotheram*†.

The medicinal earths are very numerous, and by some comprehended under the species of clays; their virtues being nearly the same: a history of them has been long expected with impatience.

Marles likewise are of different kinds and various colours: the earth generally known by the name of marle, is a light friable substance, of a middle nature between clay and chalk, but neither so fat as clay, nor so dense as chalk; and sticks to the tongue.

There are many other species of compound earths. For *Vannocbio*, an eminent *Italian* mineralist, informs us, that a sort of reddish earth often contains the richest metals: Mr. *Boyle* has found finely figur'd crystals to grow in a red earth; and he had a whitish earth sent him from the *North of England*, which contain'd a large quantity of lead. An experienced writer on the gold and silver mines of *America*, observes that gold itself is frequently disguised under the appearance of a reddish earth. And our *English* okers are richer in iron even than some ores of that metal.

* See *Boyle Abr.* Vol. III. p. 422, & 423.

† See *Phil. Transact.* N°. 164.

collected from the fumes of burning sulphur. Add that vitriols and sulphur are generated and produced from the same *matrix*, viz. the *Lapis Pyrites* abovementioned; which being dug up, exposed to the air, discharged of its redundant sulphur, ground to powder, and dissolved in water is left to shoot on slips of wood. Otherwise, it may also be produced immediately from the ancient *Misy*, by a natural solution and crystallization.

Species of vitriols.

Green.

Blue.

White.

Red.

Cyprian, what.

Sory, what.

Melenteria, what.

Principles of vitriol.

4. Vitriol then is of five kinds: 1. Green, composed of iron and spirit of sulphur, much commended for its medicinal virtues, and the best for ink. 2. Blue, compounded of much iron, and a little copper dissolved by spirit of sulphur. A solution of this in water tinges iron of a ruddy copper-colour, which discovers the admixture of copper. 3. White, which shews no great difference from green, except what it probably owes to the greater degree of heat in its origination, as is confirmed from the factitious kind; in every other respect the two perfectly agree. 4. *Chalcites*, or the true *Chalcantum*, or red vitriol; which is also near akin to the green, and resolves into the same principles. Perhaps there may be some mixture of copper in it; but its chief ingredients seem to be iron, and the acid of sulphur. 5. *Cyprian*, or *Hungarian*; which is of a perfect blue colour, and composed of copper and the same acid of sulphur. From hence arises the *Sory*, which is a hard, sharp, coarse unctuous glebous substance; seeming to be condensed juice of vitriol; of a black, or ash-colour; and which becomes vitriol again by means of water. And *Melenteria*, which is likewise of a black or ash-colour, glebous and caustic; is probably of the same origin and production.

5. In all these therefore, iron and copper make the basis; the acid of sulphur affords the solvent; the water which dilutes the acid and arranges the parts of the metal, gives the figure and transparency. Hence from the different proportion of these three, may all those diversities be accounted for, which are spoke of by the ancients. In effect, water with the acid spirit of sulphur, iron, or copper, mixed and combined in a certain proportion, form those called native vitriols (g).

6.

Natural history of vitriol.

(g) Vitriol is of two kinds, natural and factitious. The natural is found of four different colours; viz. white, blue, a bluish green, and green.

There are very large quantities of native vitriol found in caverns of the copper-mines at *Goslar* in *Germany*; being sometimes in lumps, or pieces, like icicles, of a great length and thickness: and this is sold common, tho' most people have thought it factitious; whereas it is only refined by art, or dissolved in water, and suffer'd to crystallize. The *Minera Martis solaris Hassaca*, as it is called, in tract of time deposits its sulphureous nature, and becomes vitriolic; after the manner of our pyrites, of which copperas is made.

The white vitriol comes from *Germany*, in the form of loaves or lumps, resembling white sugar; of a sweetish and nauseous styptic taste,

'Tis found in certain mines in form of a downy efflorescence; which being collected and dissolved in water, when the superfluous humidity is evaporated, it concretes into a white solid mass. It appears, upon examination, to consist of a ferruginous substance, or imperfect iron ore, with a small mixture of calamine, or lead. It is used in medicine as a gentle expeditious emetic.

Blue vitriol is differently denominated, according to the different places it comes from; as *Roman*, *Cyprian*, *Hungarian*, &c. This we meet with usually in the form of dry hard beautiful blue crystals, of a rhomboidal figure, squat, and consisting of ten sides. Its beautiful blue colour is manifestly owing to the copper it partakes of: 'tis of a very rough, or styptic taste, and accordingly is used as a styptic in medicine. This vitriol is obtain'd in various ways; viz. from vitriolic waters, earths,

6. (2) Semi-metals composed of a true metal and a sulphur combined together. To this head chiefly belong native cinnabar, which is found in mines from a coalition of sulphur and mercury melted together by the subterraneous heat; as appears from the manner of making factitious cinnabar (*b*). This, which makes the minium of the ancients, may easily be resolved again into a true sulphur and mercury. Whence it appears that a real sulphur is generated plentifully in mines, by natural means alone.

earths, stones, and particular pyrites. In *Galen's* time it was made by the natural heat of the sun, exhaling the humidity of a vitriolic water in *Cyprus*. In some parts of *Hungary* it is now made by boiling and evaporating a water of the same kind to a due consistence; then suffering it to shoot. And in some parts of *Germany* it is made by washing and boiling a particular grey earth, with differently coloured spots, looking like rust of iron and verdigrease.

The vitriol of a bluish green cast is obtained in the same manner; and its colour appears owing to its participating both of iron and copper.

The common green vitriol or *English copperas*, is made at *Depsford* in the following manner, from *pyrites*, which are round, ponderous, close stones, of a dusky colour on the outside, but having their inner substance radiated like a star from the centre to the circumference. They originally yield no taste of vitriol; and are found along the shores of *Essex*, *Sussex*, &c. When calcined, they yield a fume like that of brimstone; and leave a red calx containing iron behind. Exposed to the open air in heaps, for a length of time, they seem to ferment, heave, swell, crack, and fall to pieces; and then yield a white downy efflorescence of an acrid styptic taste: and thus the white substance of the stone seems to dissolve and fall to dust, of a saline, vitriolic and sulphureous taste and smell.

A heap of these stones, two or three foot thick, they lay in a bed well ramm'd; where, being turn'd once in six months, in five or six years, by the action of the air and rain, they begin to dissolve, and yield a liquor, which is received in pits, and thence convey'd into a cistern in a boiling-house. The liquor at length being pump'd out of the cistern into a leaden boiler, and a quantity of iron added thereto, in two or three days the boiling is compleated; care having been taken all along, to supply it with fresh quantities of iron, to restore the boiling, whenever it seems to abate; when boil'd sufficiently, 'tis drawn off into a cooler with sticks across, where it is left 14 or 15 days to shoot.

* See *Stahl, de Vitrioli Blogiis*.

7. It appears, that the diversity of colours in vitriols arises from the difference wherein the salt or acid is receiv'd: in blue, the salt is join'd with copper; in green, with iron; in white, with calamine, or some feruginous earth mix'd with lead, or tin. As to red vitriol, called *colcothar*, its colour is adventitious, and seems to arise from a calcination which the vitriol undergoes, either by art, or some subterraneous fire.

This is not only supported by the natural history of vitriol, but seems to be confirm'd by numerous analyses made of the several kinds of vitriol, and the artificial preparation of them upon such principles; so that it may pretty safely pass for a general truth, that all vitriol consists of water, a metalline part, and an acid combined: that the water gives the transparency, or crystalline form; that the acid dissolves the metal, and thus gives the colour; and that all three are thus united together.

Its uses.

The uses of copperas are numerous. It is the chief ingredient in the dying of wool, cloths, and hats black, in making ink, in tanning and dressing leather, &c. And from hence is prepared oil of vitriol; and a kind of *Spanish brown* for painters.

Natural history of native cinnabar.

(*b*) Native cinnabar is found in quicksilver-mines; though it has likewise its own mines, of which those in *Spain* are famous; it is likewise found in *Hungary*, *Bohemia*, *Italy*, and *France*. It is a hard, ponderous, metallic, and beautifully red stony substance, that breaks into shining, bright, angular pieces. It seems to be improperly called the ore of quicksilver; as, besides other reasons, being much more valuable, and bearing a higher price than quicksilver; yet affording, according to its difference, from six or seven to thirteen or fourteen ounces of true running mercury in a pound. The sulphur remaining behind, after this separation, seems also to differ from the common; and its nature seems hitherto not sufficiently known.

Antimony, if
capable of
malleability.

7. The *Stibium* of the ancients, by the *Greeks* called *στίβιον*, by the moderns antimony, consists of a true fossil sulphur, and a matter much resembling metal; which if it could be rendered malleable, would become of a perfect metalline nature, and make the seventh in the class of metals. But such method of purifying antimony is hitherto unknown; tho' Mr. Boyle affirms that a true fluid mercury had by a secret process been procured from it: and few pretenders in these days but boast they can do the like. It is fusible in the fire, and promotes the fusion of other fossils mixed with it; but being brittle in itself, communicates the same quality to the other ductile bodies it is mix'd with. It is volatile in itself, and renders almost all other bodies mixed therewith volatile in the fire. In fine, it encreases the beautiful brightness of gold: and in many things is found to approach the nature of white arsenic (*i*).

Affinity with
arsenic.

Bismuth.

8. Bismuth, or *Bisemut*, resembles antimony: it consists of thin plates or *Lamellæ*, laid on one another; imitates silver in the brightness, and whiteness of its colour: but is less friable, harder, not ductile under the hammer, gives evident indications of a sulphur in it; and by the action of an acid on it, lets go a bituminous matter; is less fixed in the fire than metals, and when mixed therewith renders them volatile and friable (*k*).

Natural history of antimony.

(*i*) Antimony has its own mines, particularly in *Hungary*, *Transylvania*, *Germany*, and several provinces of *France*. Its ore is mixed with a stony matter, from which it is separated by breaking it into small pieces, and afterwards refining it, as is practised in other imperfect metals. This makes the crude antimony of the druggists; which is a metallic, solid, heavy, brittle substance, of a lead colour, consisting of long shining streaks or needles: 'tis easily fused by fire, and flows the thinnest of all minerals; but is not ductile. There are different kinds of antimony, and it is often found mix'd with other metals. A great variety of medicinal preparations are obtain'd from it; and generally prove either emetic, cathartic, diaphoretic, or sudorific. Of late, crude antimony has frequently been given internally in powder; and is said to dissolve viscidities in the fluids, open obstructions, and give relief in cutaneous diseases, consumptions, and epilepsies. It is likewise accounted of great use in fastening animals. In external application, being mix'd with ointments, it is commended for drying ulcers, curing the itch, and other diseases of the skin: in plaisters 'tis used for resolving tumours; and in *calabria* for inflammations, and other disorders of the eyes. In chemistry it is of extensive use; as contributing to the pulverization and consequent solution of metals: the ready amalgamation of the harder metals; the animation of mercury; the extraction of metallic sulphurs; and the supposed meliora-

tion of metals. It is used in the making of pewter, and types for printing. Its regulus is said to help in the gilding of copper; and to improve tin in point of whiteness, hardness, and sound; whence also it is sometimes used in casting bells, making metalline specula, &c.

Natural history of bismuth.

(*k*) Bismuth, otherwise called tin-glass, the silver marcasite, and by some white zinck, grey lead, and the magnet of metals, is divided by naturalists into *native* and *artificial*. The *native* or *fossil* is frequently found among the silver-mines and tin-mines in *Bohemia* and *Misnia*; and sometimes also, if we may credit *Alonso Barba*, in mines of its own. Its ore, being easy of fusion, readily yields the bismuth, by a gentle flame of wood in a low-arched furnace; leaving a slag, which affords a blue glass, or *smalt*. Bismuth is readily soluble in vinegar, and communicates a saccharine taste thereto; it also dissolves in spirit of salt, *aqua fortis*, and spirit of nitre; and hence by precipitation is procured a magistery, or fine white powder, which is much esteem'd as a cosmetic, and helps to change the colour of hair. Bismuth is a principal ingredient in the making of solders, on account of the thin fusion it soon procures to metals. And M. Homberg informs us, that it considerably improves the metallic mixture design'd for printers types, by rendering it harder and less brittle.

Artificial bismuth, according to *Langius*, is prepared from tin, by cementing thin plates thereof

9. Zinck, or *Zinctum* is much like the former, but less friable (1). Zinck.
 (3) To semi-metals may also be referred all fossil, crystalline, stony and earthy matters, which have any true metalline matters intermixed with them. Such are the generality of native ores in mines, and numerous other bodies; *Ores*, the principal whereof are:
 10. *Lapis Armenus*, called also *Lapis Lazuli* and azure-stone; which is very light, of a blue colour, and spangled with golden sparks; usually said to contain a large proportion of gold (m). Lapis Armenus and lazuli.
 11. *Lapis Hematites*, which appears to be pregnant with metalline principles, bears a near resemblance to iron, and when sublimed with *Sal-ammoniac*, diffuses a rich, aromatic, sulphurous smell; whence some call it *Aroph*, or *Aroma philosophorum*, the philosopher's spice (n). Hematites. Aroma philosophorum.
 12. Load-stone, remarkable for its consent with iron; being of the same colour, and having other properties much like it. Load-stone.
 Ochre may also be probably rank'd in this class, as being the produce of iron, precipitated from mineral waters (o).

12.

thereof with a mixture of white tartar, salt-petre, and arsenic: or, as others say, by well grinding a mixture of arsenic, verdigrease, and sal-gem, with oil-olive, and afterwards adding the whole to half its weight of tin in fusion.

Natural history of zinck.

(1) Zinck, tutenag, or spelter, is a metallic, sulphureous, ponderous substance, resembling lead in colour; it is fusible and ductile to a certain degree, very hard to break, inflammable, volatile and soluble in acid menstruums. There are two kinds of it, the *German* and *Indian*, to which some add a yellow zinck, which is the produce of a certain marcasite, hitherto but little used, except in mechanical mixtures.

At *Goslar* in *Germany* 'tis run from a kind of lead-ore in a furnace of a particular structure. Zinck improves tin in brightness and hardness; and with copper makes the finest kind of prince's metal, so-called from *Prince Rupert*, its supposed inventor. The flowers of zinck are accounted drying in external application.

Natural history of lapis lazuli.

(m) The *lapis Armenus* and *lapis lazuli* are two different opaque stones, tho' frequently confounded, on account of their being often met with in the same glebe, and used indifferently for each other; as having the same virtues, only the *Armenian* stone is supposed to be more strongly purgative. This is opaque, with green, blue, or blackish spots, mark'd like the azure stone, with gold-coloured specks and friable. It is seldom used in physic; but is employ'd by the painters in making a beautiful blue colour with a greenish cast.

The *lapis lazuli* is a hard blue stone, with gold or silver-coloured specks and veins: 'tis found of two kinds, one bearing the fire and the other not. The first is brought from *Asia* and *Africa*, and is called the oriental stone; the other is softer, and dug out of the gold, silver, and copper-mines in some parts of *Germany* and *Italy*. The oriental produces the lasting beautiful *ultramarine* blue: but the *German* ultramine is easily injured by external causes, and in time turns green. The best *lapis lazuli* is of a deep blue colour, mark'd with some gold specks, hard to break, and durable in the fire. Its medicinal virtues are few, and those ill-supported, though it retains a place in some compositions.

Natural history of lapis hematites.

(n) *Lapis hematites*, or blood-stone is a ferruginous, hard, gleby, ponderous, metallic substance, of a dark red, or yellowish colour, and sometimes blackish, of an earthy astringent taste; and when broken, appears to have fine long fibres, like those of wood. It is frequently found in iron-mines, in a distinct ore; and sometimes with the load-stone, in many places of *Germany*, *Italy*, and *Spain*, the latter whereof is reckon'd the best. It is a kind of iron ore; and *Agricola* says that in the valley of *Joachim* in *Bohemia*, these stones are found so rich in iron of the best kind, as to make it worth while to run the metal from them. It is frequently used in medicine, both in substance and in preparations, as a styptic and astringent, as well internally as externally.

Natural history of the load-stone.

(o) The magnet, or load stone, is found in many countries of *Europe*, and generally in

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Other principles of fossils.

Active principle.

13. From the whole, we may be enabled to form a judgment of the principles of fossils; which appear chiefly reducible to mercury, metalline sulphurs, salts, combustible sulphurs, earth and stones. But these will be found very different, if carefully examined in different subjects: the chief active principle in them, is a volatile saline acid; those which want this, derive all their activity and motion from fire (p).

Of VEGETABLES.

Plants, what.

1. Another genus of bodies which chemistry is employed about, are vegetables, usually called plants.

2. A vegetable is an hydraulic body, (containing various vessels, replete with different juices,) which adheres by a certain part to another body, from whence, by means of this part, it derives the matter of its nutriment and accretion.

3. Hence vegetables differ from fossils, as above described, both in the diversity of their solid parts, in the different nature of their contained fluids, and in their structure, which consists of vessels and juices.

Their root.

4. Add that the external part, called the root, which imbibes the nutriment from the nourishing body to which it is joined, sufficiently distinguishes vegetables from any animal hitherto known (q).

iron-mines; but the best is brought from the *East-Indies* and *Ethiopia*. It is a kind of iron-ore, and in some parts of *Germany* they run the iron from it. When exposed to the focus of a large burning-glass, it manifestly discovers iron. It has very odd properties, and among the rest that of attracting iron, and giving it a polarity. But fire, rust, moisture, and long disuse, tend to weaken its force; tho' Mr *Boyle* gives us instances of some *English* loadstones, which retained their virtue after ignition*.

The principles of fossils.

(p) Fossils should seem to consist (1) of mercury, as the basis of many of them: (2) Of a subtile sulphur, that coagulates or fixes mercury: for even the ancients always distinguish'd two kinds of sulphur, the one volatile and combustible, and the other, which alone we have here regard to, perfectly fix'd; as being in effect a sort of concentrated fire. (3) Of salt: and (4) Of earth. All these, however, are not found in all fossils: some metals having been shown to consist of only the two first, and others only of the three last.

Whether water the universal wine of the ancients, which all bodies drink, and whereby they are supposed to grow and increase, be to be deem'd a principle, will admit of some doubt. Sir *Isaac Newton* defines it an

5. insipid salt. Others call it the chaos of all things, and 'tis perhaps the remote matter of all fossils; and may, therefore, be consider'd as constituting a peculiar class of body †.

(q) Few authors but observe the near analogy between the vegetable and animal economy and structure. Mr. *Renaume*, from a survey of plants, concludes, (1) That the root in plants, does the office of the parts contained in the belly of animals destined for nutrition; it being this chiefly that prepares, digests, alters, and changes the food into a nutritious juice, to be afterwards distributed to all the parts. 2. That the trunk and branches of trees, bear some relation to the exterior members or limbs of an animal, which it may indeed subsist without, though their rotting and mortification frequently occasions a total destruction thereof. 3. That 'tis with good reason that countrymen, in pruning and lopping trees, which they would have grow again, cover the wounds, and the remains of the stumps, with earth or clay, to prevent an extravasation, which would drain them of all their vital moisture. And hence, likewise, it is, that when the branch of a tree is broke, without the bark's being entirely separated, if the pieces be set again, and the fracture tied with a bandage, capable of retaining the sap, and excluding the access

* See *Boyle Abr.* Vol. I. p. 502, 503.

† See the chapter of water. See also *Buchur's Physica Subterranea*.

5. The solid parts of vegetables are mere earth, bound together by a viscid oily substance, so as not to be separable from each other without an open, quick fire.

6. The vessels of plants differ exceedingly both in their structure and place, the matters contained therein, and the virtues thereof (r).

7. The root is intended for fastening the plant to the ground, or for imbibing nutriment therefrom; which last office seems sometimes also to be performed by the whole surface of the plant, as in the instance of truffles. The root then is furnished with absorbent vessels, whose mouths are ranged close to each other thro' its whole surface, by which the nutritious moisture is imbibed, protruded into the canals, and by these conveyed thro' the whole substance of the plant (s).

of the air, the branch will heal again, a callus be form'd, &c. just as in a fractur'd bone*.

As to those few plants which appear to float with the water, their manner of growth is somewhat anomalous. M. *Tournefort* has shewn that all plants do not arise strictly from seeds, but that some, instead of semen, deposite or let fall a little drop of juice, which sinking in the water, by its gravity, reaches the bottom, or some rock, &c. in its way; to which it sticks, strikes root, and shoots into branches; such is the origin of coral, which by distillation yields a volatile salt.

There are some species of sea-mushrooms, particularly the *neptune's-cap*, which are not found to adhere to any body: but M. *Tournefort* observes, they have been sometimes found with a little pedicle, which might have sustain'd them. And hence he infers, that they originally grew to the bottom, and had their generation like the rest. He adds, however, that when they have lost their pedicle, 'tis probable they are fed by some juice, which the sea-water lets insinuate thro' the pores of their surface†.

Coral has been suspected by the naturalists of all ages for a sea plant; but the moderns have demonstrated it such; and even discover'd its flowers and seeds. That illustrious naturalist the Count de *Marfigli*, having long doubted the vegetable nature of coral, was at length convinced by the following experiment: having steep'd some coral, fresh gather'd, in sea-water; he perceiv'd, in a short time, that the little ruddy tubercles, which appear'd on the surface of its bark, began gradually to unfold, and at length open'd into white flowers, in the form of stars with eight points, which were sustain'd by a little calyx, divided in like manner into eight parts. Upon

taking the coral out of water, the flowers immediately closed, and return'd into red tubercles as before; which tubercles being closely squeez'd, yielded a sort of milky juice. And upon returning the coral into the water, as before, the tubercles, in an hour's time, open'd or flower'd afresh; and this was continued for six or eight days, when the buds or tubercles ceased to blow any more. In ten or twelve days they became detach'd from the coral, and sunk to the bottom, in form of little yellow balls. These tubercles, then, according to the analogy of plants, should be the powers of coral; and the milky viscid juice contained therein the semen; accordingly 'tis held, that when this juice falls on a properly disposed subject or nidus, a new coral arises therefrom.

Add, that the analysis of coral answers precisely to that of other sea plants; all of them affording a volatile urinous salt, and a thick blackish, fetid oil‡.

There are corals of divers colours; the most usual and valuable are red and white; others are *seuilemort*, carnation, green, yellow, ash-colour'd, &c.¶.

(r) The vascular structure of vegetables is rendered very apparent by an experiment of Mr. *Willughby*, cutting off some pretty big branches of birch, and making a sort of basin or reservoir, at the end thereof with soft wax; upon filling this with water, and holding the branch upright, the water in a few minutes sunk into the vessels of the wood, and running quite thro' the length, dropt out of the end considerably fast; continuing so to do, as long as water was pour'd on. The same succeeds in *ycamore*, *walnut*, &c. tho' the flux here is not so copious**.

(s) The principle, whereby the root imbibes its food, is somewhat controverted: some

* *Mem. de l'Acad. an. 1707.*

† *Mem. de l'Acad. an. 1700.*

‡ *Mem. de l'Acad. an. 1702.*

¶ *Journ. des Sçavans. an. 1710.*

** *Phil. Transact. N^o. 70*

8. These vessels may properly be compared to the mesenteric lacteals, and other absorbent veins of animals.

Some will have it effected by means of the pressure of the atmosphere, in the same manner as water is raised in pumps: but this is precarious, as being founded on the supposition, that the absorbent tubercles are void of air; besides, that the atmosphere could only raise the juice thirty-two feet high, whereas there are trees much higher. Others have recourse to the principle of attraction, and suppose the power that raises the sap in vegetables, to be the same with that whereby water ascends in capillary tubes, or in heaps of sand, ashes, and the like: but neither will this alone suffice to raise water to the tops of trees. One would suspect therefore, that the first reception of the food, and its propagation thro' the body, were effected by different means; which is confirm'd by the analogy of animals.

Some of our ablest naturalists hold water the only nutritious matter of vegetables: *Hales* and *Mr. Boyle* give us some experiments which very much favour this doctrine. The first, weighing a quantity of earth, and planting a willow therein, which he water'd with rain, or distill'd water only; in five years time raised it from five pound weight, to an hundred sixty nine pounds three ounces; and this without any greater diminution of earth than two ounces: and *Mr. Boyle* found the like experiment to succeed with squash-seed. *Dr. Woodward*, on the other hand, has some curious experiments, which seem to overturn this notion, and to prove that mere elementary water is not proper food for vegetables; the water, according to him, being only the vehicle of the alimentary matter, the earth contain'd therein, supplying all the vegetation*.

The notion of the sap's circulating, was entertain'd by several authors, much about the same time, without any communication from one to another; particularly *M. Major*, a physician of *Hamburg*, *M. Perrault*, *Marriotte*, and *Malpighi*. It has met, however, with some considerable opposers; particularly the excellent *M. Dodart*, who could never be reconciled to it.

One of the great arguments for it is, that the same experiments of ligature and incision, which evince a circulation of the blood in animals, succeed in the like manner in plants; particularly in such as abound with sap, as the great tithymal milk-thistle, &c. For a metalline gill being here fix'd tight round

* See the article Water.

the stem; the part above it is found to swell very considerably, and that below it a little. Whence it appears, that there is a juice ascending from the root, and likewise another descending from the branches; and that the latter is thicker than the former; which quadrates exactly with the common system; the juice being supposed to arise in capillary vessels, in form of a subtile vapour, which condensed in the extremes of the plant, by the neighbourhood of the cold air, turns back in form of a liquor, thro' the more patent pipes of the inner bark.

M. Dodart, instead of the same juice's going and returning, contends for two several juices; the one imbibed from the soil, digested in the root, and thence transmitted to the extremes of the branches, for the nourishing of the plant; the other, receiv'd from the moisture of the air, in at the extremity of the branches: so that the ascending and descending juices are not the same. One of his chief arguments is, that if two trees of the same kind be transplanted in one day, after first cutting off their roots and branches; and if after they have taken root again, some of the new shoots put forth each year be cut off one of them, it will not thrive half so well, notwithstanding its root and trunk's being entire, as the other. This he conceives to be a proof of the plant's deriving nourishment by the branches; and concludes it to be of an aerial nature, because form'd of the moisture of the air, dew, &c. whereas that imbib'd from the soil is terrestrial, &c. †

But what seems to decide the controversy in favour of a circulation, is the following experiment of the reverend *Mr. Laurence*: on a branch of plain jessamin, whose stem spreads into two or three branches, inoculate a bud of the yellow striped jessamin; and as the tree comes to shoot the following spring, some of the leaves will be found tinged here and there with yellow; and this even on the other branches not inoculated; till, by degrees, the whole tree, even the very wood of the young shoots, appear all variegated, or striped green and yellow.

What course the juice takes after it is imbibed by the roots, is not very clear; the vessels that take it up to convey it thro' the plant, are too fine to be traced: and hence it has been controverted, whether it is by the bark, or the pith, or the woody part, that the plant is fed.

Some

† *Hist. de l' Acad. Roy. an. 1709.*

9. The juice thus derived from the alimentary body is not yet of the proper nature of vegetables, but being crude, retains the disposition of the mother from whence it was drawn: yet this, which is usually earth, or water, receives back, sooner or later, whatever it had imparted; in as much as bodies generated from the earth and water, when at last they decay and die, return again into air, water or earth, and fall out of the air into the bosom of the earth, or water, in form of dew, mist, snow, hail, hoar-frost, or rain: so that earth is a chaos or colluvies of all bodies past, present, and to come, from whence they all arose, and into which they will all certainly return.

10. W2-

Some contend for the *wood*, which they observe to consist of slender capillary tubes, running parallel to each other from the root up to the trunk, proper to receive a fine vapour: in the ascent whereof, the fibres become open'd, and their substance increas'd. And thus it is, that the trunks of trees increase in circumference, by *ingestion*.

The more common opinion is for the *bark*; the juice raised by the capillaries of the wood, is here supposed to descend by the larger fibres placed in the inmost part of the bark, immediately over the wood; in which descent, the sap, now sufficiently prepared, adds a part of its substance to the contiguous wood; and thus increases by *apposition*. And hence it is, that hollow, carious trees, which have neither pith nor wood, except just enough to sustain the bark, do grow and bear.

What confirms this, is an observation of Dr. *Tonge*, communicated to him by an eminent planter in *Gloucestershire*; viz. that by binding a tree round about very closely and strongly with cords, so as to intercept what rises betwixt the bark and the wood, the blooming and bearing of the tree is retarded: and by such means, in some years, when the open weather bringing on too early a spring, endangers the destruction of the blossoms, &c. he has often prevented a scarcity of forward fruits, which are usually nipped by the late frosts*.

Add, that in the journals of the royal society, Dr. *Beal* assures us from his own experiment, that if a circle be drawn round a common *English* tree, by incision to the solid timber; how thin soever the knife be, and tho' nothing at all be taken away, the tree will die from that part upwards: only the part below the cleft will grow on and prosper, notwithstanding the incision. He adds, that he has seen some old huge ashes, which had been bared of their bark by the deer, from the root to the height of four feet quite round; and yet have continued their growth for many years; and some bark, which was

left in some few places no broader than a hand, had a fresh verdure more lovely than any other part of the tree†.

To this others object, that there have been trees known to grow, and put forth leaves and flowers for several years, without any bark; particularly that elm in the *Tuilleries*, whereof an account was given to the royal academy by *Monf. Parent*. Add, that the plantane and cork tree cast their barks, and get new ones, as serpents cast their skins; and 'tis hard to conceive how the bark, during such transition, should contribute to the support of the plant. Beside, in some plants, as the vine, elder, &c. the bark is very inconsiderable, but the pith very copious; which should seem to intimate, that they are fed by the latter rather than the former. And it is further observable, that in proportion as they grow old, the pith becomes fibrous and woody; which shews, that the pith is dispos'd by nature to form woody fibres; and therefore may be proper to furnish wood with its nutritious juice.

Lastly, it is observ'd, that if you cut off a ring of bark around a tree, three or four inches broad, parallel to the horizon; and thus lay the wood quite bare, so that the tree cannot receive any nourishment by the bark; yet will it not lose its leaves; nay, it will bear flowers and fruit the same year, and this double its usual crop: tho' in the succeeding winter, all the branches above the incision will die. Hence *M. Parent* argues, that the juices which produce and nourish the leaves, the flowers, and fruit, do not ascend by the bark, but by the *pith*; but those which nourish the wood and bark, by the *bark*: and that the quantity of juice which should naturally have passed by the pith, having been augmented by that which should have passed by the bark, is the cause of the extraordinary produce of fruits and flowers. In effect, says *M. Fontanelle*, the pith of plants, like the *medulla* in animals, is a collection of an immense number of little vesicles, which

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seem

* *Philos. Transact.* N^o. 68.

† *Phil. Transact.* N^o. 46.

10. Water, spirits, oils, salts, and all other bodies are hid in the earth, where being agitated and mixed, especially with water; by subterraneous, artificial, and solar fire they are brought to the roots of plants spread in the ground.

11. So also the water of the ocean, rivers and lakes, receives and dissolves terrestrial bodies dispersed thro' the atmosphere.

These

seem destin'd to filtre and elaborate a finer juice than should seem necessary for the nutrition of mere wood*.

In answer to all this, the retainers to the bark alledge, that the parts of a tree disjoined from their whole, may take with them a stock of nutritious juice sufficient to make them vegetate. Thus, the branches of elder willow, &c. cut from the stock, will shoot forth leaves, twigs, &c. without being ever put in the ground; and pieces of wood, half dry, have been known to do the same: which must be owing to some remaining juice, agitated and subtilized to a certain degree by the warmth and action of the air. And if parts thus cut off may vegetate, much more may those which still adhere to the tree, which can scarce ever be entirely deprived of new juices; since, tho' the bark should not furnish them any, yet they will receive some from the *blea*, or that part of the wood which was last form'd, and has not altogether lost its cortical nature. This accounts for the phenomena of the elm in the *Tuilleries*, the ashes of Dr. *Tonge*, and the olive trees of M. *Magnot*; excepting that in this last instance, the vegetation is more abundant, after taking away the bark than before; which gives a new difficulty.

To solve this, M. *Renaume* observes, that the buds, out of which flowers and fruits arise, are form'd at the same time as the young branches whereon they grow; for old wood never bears any; that the buttons wherein these fruit-buds are contain'd, are easily distinguish'd from the buds that yield nothing but wood: that these fruit-buds require nothing but to be expanded, which sometimes does not happen, in perfection, till the second year; that it is easily possible this expansion should not succeed so well, when, beside a competent stock of juice in reserve, new juices are brought by the bark, in too great plenty to be so gently attenuated and subtilized, for entering the minute vessels of the forming parts. Thus, by cutting off the communication of new juices by removing some of the bark, the juice is disposed to insinuate more readily into the little vessels;

and thus to give rise to a greater number of flowers and fruits.

As to the elms of *Luxembourg*, M. *Renaume* examined them himself, and found they were not so naked, but that there were some remains of the inner rind or *blea*, whereby the juice might mount: and the same doubtless was the case of the ashes mention'd by Dr. *Tonge*. Add, that M. *Maraldi* observed to the royal academy, that a shoot of a plumb-tree having been broke, so as only to hang by a piece of bark; yet, upon raising and setting the fractur'd parts, it produced wood, flowers, and fruit.

From the same observation of the elm of *Luxembourg*, M. *Renaume* even draws a conclusion in behalf of this system, viz. that it is the bark forms the *blea* or bleak; and that as the *blea* is the wood last form'd, all the wood comes from the bark.

The bark, *liber*, is to be conceiv'd as consisting of a number of cylindric and concentric surfaces, whose texture is reticular, and in some trees apparently extensible every way, by reason the fibres thereof are soft and flexible. While in this condition, they are either hollow, and so real canals; or if they be solid, their interstices are canals. The nutritious juice which they are continually receiving, part of which is detain'd in them, makes them grow both in length and thickness, strengthens and brings them nearer each other. Perhaps the longitudinal fibres may grow the fastest. By such means the texture, which before was reticular, becomes an assemblage of strait fibres, ranged vertically, and parallel one behind another, i. e. it becomes a new woody substance, under the name of *blea*.

While the *blea* remains any thing soft, and retains somewhat of the nature of a bark, it it may maintain a feeble vegetation: but when it is grown absolutely hard and woody, it can no longer contribute thereto. The vegetation of young branches is the most lively and vigorous, and the only one that goes as far as the flowers and fruits, by reason they are little else but bark.

For the *pith*, as the woody substance of the

12. These crude humours therefore which, in the spring-time especially, are found in great plenty, and moving with a brisk motion thro' the bodies of plants, are to be considered as thin, watery, and somewhat acid; which is confirmed by the juice trickling in *March*, from wounded beeches, walnut-trees, or vines, received in vessels (1).

the trunk becomes more woody, the pith is compressed and straiten'd, to such degree, that in some trees it quite disappears: whence it appears, that its office in vegetation is not very important, since its use is not perpetual. By its spongy structure, it should seem fitted to receive any superfluous moisture transuding through the pores of the woody fibres: and if by the excess of such moisture, or the like cause, it corrupt and rot, as frequently happens in elms, the tree does not grow the worse for it: A convincing proof it is of no great use*.

(1) From the latter end of *January* to the middle of *May*, trees will bleed: those that are said to run first, are the poplar, asp, a-bele, maple, sycamore; some, as willows, and the birch, are best to tap about the middle of the season; and the walnut towards the latter end of *March*. They generally bleed a full month in the whole. The best time of the day for tapping is about noon. The sycamore will run in hard frost, when the sap freezes as it drops. When a large walnut would run no longer in the body or branches, it would run at the roots; and that longer on the south or sunny side, than on the north or shady side†.

To obtain the greatest store of sap in the shortest time from the body of a tree, bore it quite through the pith, and the very inner rind on the other side, leaving only the bark unpierced on the north-east side: this hole to be made sloping upward, with a large auger, and that under a large arm near the ground. This way the tree will in a short time afford liquor enough to brew with: and with some of these sweet saps one bushel of malt will make as good ale, as four bushels with ordinary water. Sycamore is said to yie'd the best brewing-sap, being very sweet and wholesome||.

The bleeding of the birch has afforded naturalists matter of much speculation. *Willoughby*, *Ray*, *Lister*, &c. have made a great number of experiments and observations thereon, which may let some light into the business of vegetation in general.

In the birch, the sap issues out at the least twigs of branches, and the smallest si-

cles of roots, in proportion to their bigness; the gravity always promoting the discharge: so that a branch or root which bends downward, will yield much more juice than another of the same size erect.—Branches, and young trees quite cut away, and held perpendicularly, will bleed; and if the tops be cut off, and inverted, they will bleed also at the little end.—In birches, no sap issues out at the bark, be it ever so thick; but as soon as the bark is quite cut thro', they then first begin to bleed: the bark being quite off for an hand's breadth round, abates the bleeding of the tree above the pared place.—A wound made before the sap rises, will bleed when it does rise.

The changes of weather have a great effect on the bleeding of plants; insomuch that *Dr. Tange* is of opinion, could we but observe it to advantage, we should hence have much better indications of the alterations of weather, in respect of heat, cold, moisture, &c. than from any weather-glasses. When the weather changes from warm to cold, the birches cease to bleed; and upon the next warmth begin again: but, which is very remarkable, the contrary always obtains in the walnut-tree, and frequently in the sycamore, which, upon a fit of cold, will bleed plentifully, and as that remits, stop: a morning-sun, after a frost, will make the whole bleeding tribe bleed afresh.

Lastly, a culinary fire will have the like, or greater effect than the sun, and immediately set them a bleeding in the severest weather. Branches of maple and willow, cut off at both ends, will bleed, and cease at pleasure, again and again, as you approach them to, or withdraw them from the fire; provided you balance them in the hand, and often invert them, to prevent the falling and expence of the sap: yet, being often heated, they will at length quite cease, tho' no sap was at any time sensibly lost: and when they have given over bleeding, by being brought within the warmth of the fire, the bark will be found very full of juice.

A hard ligature, made within a quarter of an inch of the end of a wood-bine branch, *Dr. Lister* assures us, did not hinder its bleed-

* See the *Memoirs de l'Acad. an.* 1711.

|| *Id. ibid.*

† *Dr. Tange, in Philos. Transact. N° 43, &c.*

13. The same juice being afterwards agitated by the structure of the plant, the fire, both subterraneous and solar, the oscillations of the air, the vicissitudes of moist, dry, cold and hot weather, and the change of day, night, and seasons of the year, is protruded thro' the several vessels of the plant; and thus gradually changed and further elaborated, so as to form a new and peculiarly vegetable juice proper to each part of the plant.

The leaves.

14. The leaves, by the structure, number, and fineness of their vessels, expose their finest juices almost naked to the air, in a surface much enlarged; which is liable to be actuated from divers causes. By such means these juices are extremely altered, and by further coction reduced to a peculiar vegetable nature: in fine, they do the office of lungs; as appears from *Malpighi's* observations (u).

15. The juices peculiar to the leaves are a honey-dew found on the surface thereof in summer evenings, also a wax, manna and balm; which being agitated and concocted by the sun's heat, and afterwards condensed by the ensuing cold of the night, may be gathered off them (x).

ing at all, when brought within the warmth of the fire.—Maple and willow branches, quite bared of bark, and brought to the fire, shew no moisture at all. The same, half bared of bark, would bleed only from those half of circles cover'd with bark. A branch of ivy, of itself, bled a liquid yellowish rosin from the bark, and near the pith; but, when brought to the fire side, bled a thin, dilute, colourless sap, from the intermediate wood-circles. One, or both ends of the pith of a willow being sealed up with hard wax, it will yet bleed freely by the fire.—Branches of willow cut off in a very severe frosty morning, and brought within the air of the fire, would shew no moisture at all; no, not when held till warm, and often and long turn'd; yet the same branches, after laying all night on a glass-plot, did, next morning, when the frost was broke, freely bleed.—Lastly, a twig of maple, whose top had been cut off before, and had then bled; being now taken off from the tree, and brought within the air of the fire, and held with the formerly cut end downwards, would not run at all; but with the other end down, run apace*.

(u) The great importance of the leaves to the fruit, appears from common observation, viz. that when the caterpillars seize on a tree in the fruit season, they only feed on, and destroy the leaves; and yet the consequence hereof is, that the tree shall frequently appear as if dead, and the fruit prove abortive †.

(x) Honey was anciently taken for a dew that fell on flowers; but what proves this a

The mistake is, that the bees only gather it after the sun is up, when there is no dew left. It must, therefore, either be a liquor prepared in the flower, and excreted by its proper vessels, like manna; or rather the fine dust, or *farina secundans* of the apices: for according to the observations of *M. du Verney*, the bees, when in search of honey, fix on no other parts but the stamina and apices, and not on such as yield any liquor.

What seems very remarkable is, that honey, in virtue of its vegetable nature, is discover'd by *M. Lemery*, to contain iron. Which discovery may, perhaps, serve as an answer to *M. Geoffroy's* chemical question, viz. *Whether there is any part of a plant without iron?* For if so delicate an extract from the finest part of the flower, and this further elaborated in the little viscera of the insect, be not clear of iron, we may despair of seeing any so †.

We have two kinds of honey, *white* and *yellow*: the white, called also *virgin honey*, trickles out, spontaneously, from the comb, when inverted, &c. The second is expressed from the combs, in a press, after having first soften'd them with a little water over the fire. There is also an intermediate sort, of a yellowish white colour, drawn by expression without fire.

To procure the wax from the combs for use: the honey being separated from them, they put all that remains in a large cauldron, with a sufficient quantity of water; and thus, by means of a moderate fire, melt it. This done, they strain the water, &c. off, through a cloth in a press. Before it grows

* *Philos. Transact.* No. 48, 57, 58, 68.

† See the *Hist. de l'Acad. an.* 1707.

† *Mem. de l'Acad. an.* 1707.

16. The like obtains in the flowers, whose *Calices*, *Petalæ*, *Stamina*, and *Flowers*. *Apices*, take up the juice, as prepared in the leaves, mature it further, and give it the proper characteristic nature of the plant; continuing to preserve, feed, and fit it for the use and support of a new embryo, in time to be generated. Thus much we infer from the affinity and neighbourhood of the flowers and leaves, the origin of the buds, and the structure of the flowers produced therefrom (*y*). Here is formed that sweet, fragrant, vital, refreshing spirit

grows cold, they scum it well, and cast it into moulds.

This is the *yellow wax*, which blanched and purified makes the *white-wax*.

(*y*) The generation of plants bears a near analogy to that of some animals, particularly such as want local motion: as muscles, and other immoveable shell-fish, which are hermaphrodites, and have the genital organs of either sex.

The flower has been allowed for the *pudendum* of a plant: but the design of so much mechanism, and so many parts, was but little understood. To instance in a *tulip*: its flower consists of six leaves, in the middle whereof arises the pistil, and around that are rang'd a number of little threads, which terminate a-top in little bunches replete with a fine powder. This is the general structure of flowers; tho' we find it diversified a thousand ways, some species appearing to want one part, and some another, and some even the whole flower.

The dust contained in the *apices*, M. *Tournefort* took to be only a sort of excrement, remaining of the food of the fruit; and the *stamina* to be no other than excretory ducts. But M. *Morland*, M. *Geoffroy*, and other of the later authors, are agreed on assigning them nobler uses. On their principle, the *stamina*, with the *apices* and *farina*, make the male part of the plant; and the *pistil* the female.

At the bottom of the pistil of the lilly, Mr. *Bradley* observes a vessel, which he denominates in a particular manner the *uterus*, or womb: it contains three ovaries, which are filled with little eggs, or rudiments of fruit, like those found in the *ovaria* of animals; and which, he adds, always decay, and come to nothing, unless impregnated with the *farina* of the same plant, or some other of the same kind. The *stamina*, according to him, serve for the conveyance, or perhaps the secretion of the male sperm, to be perfected in the *apices*, which answer to the *vesiculæ seminales*; whence, being emitted into the orifice of the pistil, it is either conveyed thence into the utericle, to fecundify the female *ova*; or it is lodg'd in the pistil, and by some magnetic

power draws the nourishment from other parts of the plant into the embryo's of the fruit: and thus makes them swell, grow, &c.

Accordingly, the disposition of the pistil, and *apices* about it, is always such, as that the *farina* may fall on its orifice: 'tis usually lower than the *apices*; and when we perceive it grown higher, we may conclude the fruit has begun to form itself, and has no further occasion for the male-dust. Add, that as soon as the affair of generation is over, the male parts, together with the leaves, fall off; the rest of the work being left to the female: and at the same time, the pistil, or neck of the *uterus*, begins to contract itself. Nor must it be omitted, that the top of the pistil is always either cover'd with a kind of velvet-facing, or emits a gummy juice, the better to catch and retain the dust of the *apices*. In flowers that turn downward, the pistil reaches much lower than the *stamina*, that the dust may fall in sufficient quantity from their *apices* for the business of impregnation.

This system of vegetable generation favours much of that admirable uniformity, every where observed in the works of nature; but 'tis experience alone must determine for it. Accordingly, M. *Geoffroy* assures us, that in all the observations he had made, the cutting off the pistil, before it could be impregnated by the *farina*, actually render'd the plant barren for that season, and the fruits abortive: And the like has been observ'd by Mr. *Bradley* and others.

In many kinds of plants, as the oak, pine, willow, &c. the flowers are sterile, and grow separate from the fruit: but these flowers, M. *Geoffroy* observes, have their *stamina* and *apices*, whose *farina* may easily impregnate the rudiments of the fruit, which are not far off.

Indeed, there is some difficulty in reconciling this system with a certain species of plants which bear flowers without fruit; and another species of the same kind and denomination, which bear fruit without flowers: such are the palm, hemp, hop, poplar, &c. which are hence distinguish'd into *male* and *female*. For how should the *farina* of the male here come

spirit, or *aura*, which ripe flowers diffuse, and which, by its genial odour proves beneficial to the embryo: it is in effect of a most pure and excellent nature, easily debased and spoiled by the mixture of other matters.

17. Here also is produced the true honey, which exuding, is received into the *Cotyle*; which are admirably contrived by nature and fixed to the bottom of the *Petala*. The bees sipping up this juice, convey it into their utricles, from whence they afterwards disgorge it into their combs, and seal it up with wax. On the *Apices* of the *Stamina*, as well as on the leaves themselves, is also found wax; which the same insects scrape off with their rough feet, form into globules, lay upon the hind part of their *Abdomen*, and thus carry to their hives, to be of use for making and sealing up their combs.

Seed.

18. The fruit is the part wherein the seed is conceived and formed. The seed is the *Embryo* of the plant, with a *Placenta*, or *Cotyledon*, either single, double, or manifold, to which the *Embryo* is fastened by an umbilical string (*z*). The *Cotyledons* usually contain a balsam, which is repositied in proper cells, and

come to impregnate the *ova* of the female? This difficulty M. *Geoffroy* solves, by supposing the wind to be the vehicle that conveys the male dust to the female *uterus*: which is confirm'd by an instance from *Jovianus Pontanus*, of a single female palm-tree growing in a forest, which never bore fruit; till having risen above the other trees of the forest, and being then in a condition to receive the *farina* of the male by the wind, it began to bear fruit in abundance.

For the manner wherein the male dust fecundifies the *ova*, M. *Geoffroy* advances two opinions; corresponding to the two systems of animal generation: the first, that the *farina* being always very sulphurous, and consisting of subtle penetrative parts, when it falls on the pistil, resolves; and its more active parts penetrating into the ovary and *ova*, excite a fermentation, which putting the latent juices of the young fruit in motion, occasions the parts to unfold. In this hypothesis the grain or ovum is supposed to contain the plant in miniature; and only to want a proper juice to put it upon expanding.

In the second, the *farina* of the male plant is supposed to be the first germ, or *semen* of the new plant; and that it needs nothing to enable it to unfold and grow, but a suitable *nidus*, with proper food, which it finds prepared in the ovary.

This latter opinion seems more agreeable to observation; for the little embryo's of the ovary, view'd with the best microscopes, don't discover the least appearance of a bud before the *apices* have shed their seed. In leguminous plants, if the *petala* and *stamina* be removed, and the pistil, or part which becomes

the pod, be view'd with a microscope, e'er yet the flower be blown; the little, green, transparent *vesiculae*, which are to become the grains, will appear in their natural order, but without showing any thing else beside the mere coat or skin of the grain. If the same observation be continued for several days successively in other flowers, as they advance, the *vesiculae* will be found to swell, and by degrees to become replete with a limpid liquor, wherein, when the *farina* comes to be shed, will appear a little greenish speck or globule, floating about at liberty. This corpuscle at first shews no signs of organization; but, in process of time, as it grows in bulk, we begin to distinguish two little leaves or horns: the liquor wastes insensibly, as the corpuscle grows, till, at length, the whole grain becomes solid and opaque; and then, upon opening it, we find its cavity fill'd with a young plant in miniature, and easily descry a *plumula*, or future stem; a *radicle*, or root; and the *lobes* of the bean or pea.

It may be added, that the *vesiculae*, or grains, have little apertures which correspond to that of the pistil, by means whereof the small particles of the *farina* will find an easy passage into the embryo of the grain. To this aperture or *vicatricula*, the radicle, when form'd, corresponds; and thro' this it passes, when the grain comes to germinate*.

(z) 'Tis very remarkable, how the plumule, or future stem should always get uppermost; and the radicle, or root, be turned downwards; and this too, perpendicularly to the horizon: and not only so, but if, by any external means, the stem be diverted from this perpendicularity, and bent, for instance, to-

wards

* See the *Memoirs de l'Acad. an.* 1711.

and appears to be the last and highest preparation of the moist kind, which nature here lays up for the use of her new offspring. In this is an oily, tenacious matter which repels all other moist things, defends the *Embryo*, and by its tenacity retains and fetters the thin, pure spirit, which is the ultimate bounds and object of the actions of plants, and which would otherwise easily fly away. This the alchemists call the *Spiritus rector*, or presiding spirit, inhabitant of sulphur, *Archæus* and servant of nature. This oil is too gross ever to enter the fine vessels of the *Embryo*.

wards the earth; instead of persevering in that direction, it makes an angle or elbow, and redresses itself.

The same is observed in trees, &c. blown down, with their roots, by the wind; or in those planted in pots, upon turning the pot on one side.

Now, the seed from which a plant arises, being the plant itself in little; 'tis easy to suppose, that if it be deposited in the ground, with the plumule perpendicularly upward, and the radicle downward, the disposition should be maintained in its future growth. But 'tis known, that seeds sown, either of themselves, or by the help of man, fall at random; and among an infinite number of situations of the plumule, &c. the perpendicular one upwards is but one: so that in all the rest, 'tis necessary the stem and root do each make a bend, to be able, the one to emerge directly upward, the other downward. Now, what force is it effects this change, which is certainly an action of violence?

M. *Dodart*, who first took notice of the phenomenon, accounts for it, by supposing the fibres of the stem of such a nature, as to contract, and shorten, by the heat of the sun; and lengthen by the moisture of the earth: and on the contrary, the fibres of the root to contract by the moisture of the earth, and lengthen by the heat of the sun. On this principle, when the plantule is inverted, and the root a-top; the fibres of the root being unequally exposed to the moisture, *viz.* the lower parts more than the upper, the lower will contract more; and this contraction be promoted by the lengthening of the upper, from the action of the sun. The consequence whereof will be, the root's recoiling, insinuating further into the earth, and getting beneath the body of the seed. In a word, the earth draws the root toward itself, and the sun promotes its descent; on the contrary, the sun draws up the plume, and the earth, in some measure, sends it towards the same*.

M. *de la Hire* accounts for the same per-

pendicularity, by only conceiving the root to draw a coarser and heavier juice; and the stem a finer, and more volatile one: in the plantule, therefore, we may conceive a point of separation; such, as that all on one side, *e. gr.* the radical part is unfolded by the grosser, and all on the other by more subtle juices. If the plantule then be inverted and the root a-top; as it still imbibes the grosser and heavier juices, and the stem the lighter; the point of separation being conceived as the fixed point of a lever, the root must descend, and at the same time, that the volatile juices imbibed by the stem, tend to make it mount. Thus is the little plant turned on its fix'd point of separation, till it be perfectly erect †.

The plant thus erected, M. *Parent* accounts for the stem's continuing to rise in the vertical direction, thus: the nutritious juice being arrived at the extreme of a rising stalk, and there fixing into a vegetable substance; the weight of the atmosphere must determine it to fix in a vertical position; so that the stalk will have acquired a new part, perpendicularly over the rest; just as a candle, which held any how obliquely to the horizon, the flame will still continue vertical, by the pressure of the air. The new drops of juice that succeed, will follow the same direction, and as all together form the stem, that must of course be vertical, unless some particular circumstance intervene.

Add, that whereas the branches are likewise observed, as much as possible, to affect perpendicularity; insomuch, that tho' they be forced to shoot out of the stems horizontally, yet in their progress, they erect themselves; M. *Parent* solves this from the vertical tendency of the nutritious juice up the stem: for the juice being received, in this direction, into the new tender bud, finds at first little resistance; and afterwards, as the branch grows firmer, it furnishes a longer arm of a lever to act by ‡.

Lastly, M. *Astruc* accounts for the perpendicular ascent of the stems, and their redressing themselves,

* *Mem. de l'Acad. an. 1700.*

† *Mem. de l'Acad.*

‡ *Mem. de l'Acad.*

19. The spirit being invigorated by a vegetable power, probably breathes a vital principle, and impresses the specific character on the food destined for the *Embryo*; by which means every thing afterwards turns to the proper nature of the plant: a power which seems peculiar to this alone; for when the spirit is exhal'd, the oil remains inert and vapid. In this spirit is the fragrant odour and proper taste of the plant lodged; and even its peculiar colour has a near dependance hereon. This, *Isaac Hollandus* in his phraseology, calls *Quinta Essentia*. In the mean time, as the dry and brittle fibres of plants require an oil to supple and make them flexible, without danger of breaking; there is another kind of oil lodged in plants, which runs thro' certain vessels placed along the woody filaments in the middle of the substance thereof, and which upon heating the wood, distils or trickles out, and may by heat, or length of time, be easily converted into a balsam, or rosin (*a*). The oil of plants being con-

cocted

themselves, when bent; on these two principles. 1. That the nutritious juice arises from the root to the top, in longitudinal tubes, parallel to the sides of the plant, which communicate, either by themselves or by means of other horizontal tubes, proceeding from the circumference of the plant, and terminated in the pith. 2. That fluids contain'd in tubes, either parallel, or oblique to the horizon; gravitate on the lower part of the tubes, and not at all on the upper.

For hence it easily follows, that in a plant posited either obliquely, or parallel to the horizon, the nutritious juice will act more on the lower part of the canals, than the upper; and by that means insinuate more into the canals communicating therewith, and be collected more copiously therein: thus the parts on the lower side will receive more accretion, and be more nourished than those on the upper; the consequence whereof must be, that the extremity of the plant will be obliged to bend upward.

The same principle brings the seed into its due situation at first: in a bean planted upside down, the plume and radicle are easily perceived, with the naked eye, to shoot, at first, directly, for about an inch; but thenceforth they begin to bend, the one downward, and the other upward.

The like is seen in a heap of barley, to be made into malt, in a quantity of acorns laid to sprout in a moist place, &c. each grain of barley, in the first case, and each acorn in the second, has a different situation: and yet all the buds tend directly upward, and the roots downward, and the curvity, or bend they make, is greater or less, as their situation approaches more or less to the direct one, wherein no curvature at all would be necessary. Now, two such opposite motions cannot arise, with-

out supposing some considerable difference between the two parts. The only one we know of, is, that the plume is fed by a juice imparted to it by tubes, parallel to its sides; whereas the radicle imbibes its nourishment at all the pores in its surface. As oft, therefore, as the plume is either parallel or inclined to the horizon, the nutritious juice feeding the lower parts more than the upper, will determine its extremes to turn upward; for the reasons already assigned. On the contrary, when the radicle is in the like situation, the nutritious juice penetrating more copiously thro' the upper part than the under, there will be a greater accretion of the former than the latter; and consequently, the radicle will be bent downwards. And this mutual curvity of the plume and radicle must continue till such time as their sides are nourish'd alike, which cannot be till they are perpendicular *.

(*a*) There are three principal *balsms* or *balsams* in use among us; viz. balm of *Gilead*, of *Peru*, and *Capiwi*. The first, which gives the denomination to all the rest, issues out at incisions made in the body of a tree, called *balsamum*, growing in *Egypt* and *Judea*. The juice, called also *opo-balsamum*, at first is liquid, but afterwards hardens into the form we see it in. 'Tis rarely had unsophisticated. The marks of purity and goodness are, to have a brisk pungent smell, nothing tart, to be easily dissoluble, astringent and pungent to the taste. Its colour is a golden yellow, and its flavour has somewhat of the citron. The fruit of the tree, called *carpo-balsamum*, and the wood *xylo-balsamum*, have somewhat of the virtue of the balm itself.

The balsam of *Peru* is differently denominated, according to the parts it is obtained from: *balm of incision* is a whitish, viscid juice, distilling from incisions in the tree; and afterwards

* *Mem. de l'Acad. Royale des Scienc. an. 1708.*

cocted by the summer's heat, and being less exposed to perspire than the other humours, is drawn forth into the bark, which is furnished with *Lacuna*; answering to the *Membrana adiposa* of animals. Here it is stopp'd and collected together by the autumnal cold, and serves, in the course of the winter, as a kind of lining and fat to defend the body of the plant, and prevent its being injured by the frost, or soaking rains. It always contains an acid spirit which is a preservative from rotting.

20. In some *Asiatic* and *Indian* plants the whole value consists in the oil of the bark; particularly in the instance of cinnamon, whose bark is replete with that celebrated oil, more priz'd than gold it self. The bark of the root of the same plant yields a surprizing oil, of great medicinal virtue, from its smell falsely called camphire. The *American* tree, *sassafras*, likewise contains a noble oil in its bark; and the like is found in several medicinal plants of *Europe*, as caper, tamarisk, ash, and the famous *American quinquina*, whose chief virtues are lodged in the bark. This oil in the winter-time is found plentifully in the bark, but in the summer and spring the warmth of the air makes all the juices of the plant, which are impregnated with the specific water, salt, and *sapo* of the plant, pass easily through this external tegument of trees, called the bark: whence of late the chemists have found means of procuring very different things from the bark, besides what was formerly done.

21. This native oil of the bark, when first collected, is liquid, but after continuing some time, and becoming gradually inspissated by the sun's heat, it appears in the form and thickness of a balsam, and changes its name accordingly; by a still longer continuance, and a more intense heat, it grows yet thicker, and becomes a kind of semi-resin; and by a further increase, or continuation of the same causes, the oil at length acquires both the nature and name of a resin: which from this origin becoming more exhausted of its acid spirit, will wholly burn in the fire, liquify by the same, dissolve and mix with oil, obstinately refuse to mix with water, harden in the cold, and when cold, lay aside its oleaginous tenacity, and become friable (b). The resin it self being still further concocted, and consequently hardened, is called colophony (c).

wards dried and hardened. *Dry balm*, is of a reddish colour, and oozes from the tips of the branches cut off for that purpose. It is like milk at first, and only reddens by being exposed to the sun. *Balm by lotion* is black, and comes from the bark, and from little branches and leaves chopt small and boil'd together.

The balsam of *Copau* or *Cayivi* comes from *Brazil*. It is in form of an oil; and is either thick or transparent: the first, white, and of a resinous taste; the second more on the yellow.

(b) The pitch in use among us, is said by some to be a gum issuing from the larch; mastic, or turpentine tree: but in reality is no more than the juice of the pine, or fir, burnt and reduced into resin, with a mixture of tar, to

give it the colour. Sir G. Wheeler gives us the way of preparing pitch, as practised in the *Levant*: a ditch being dug in the ground, two yards wide at top, but growing less and less towards the bottom; they fill this pit, with branches of pine; chusing such as have the most gum, and observing first to slit them into little shivers, which they lay over one another, till the place be full. This done, they cover the pit with fire; which burning the wood, the pitch falls down, and trickles out at a little hole made in the bottom of the pit.

(c) To this class belong turpentine, mastic, camphor, &c.

Some naturalists distinguish two kinds of resins, *liquid* and *solid*. The first is the juice,

U

just

22. Here is also found another juice called gum; which is viscid and tenacious, liquifies by the fire, and burns therein, and in the cold, unless it be very severe, retains its tenacity; yet perfectly dissolves in water. This oily mucilage invests the buds of trees, and thus covers and defends them, but melts by a moist warmth, and thus easily disengages it self; nor does it harden into a crust, which might be detrimental to the tender growing buds.

23. When this gum happens to mix with the rosin about the bark, which is frequently the case in umbelliferous plants, a new juice arises herefrom, called a gummy-rosin: one part whereof is of a guminous nature, and easily dissolves in water; the other, like a rosin, flies from water and readily mixes with oil. This property is found in *aloes*, *galbanum*, *myrrh*, and several others.

Peculiar
juices.

24. Lastly, in every plant is found one proper, or specific juice, formed by the joint force or result of all the parts of the body successively apply'd to the crude juice imbib'd; and being thus ultimately prepared, contains the true properties of the plant, and the virtues arising from them: this can scarce be referred to any class of known things, but must be considered as a thing singular and of its own kind.

25. If a leaf of the greater celandine be viewed as it grows on a living, vigorous plant; the fibres may be seen issuing from the stalk of the leaf, and opening and dispersing themselves thro' the whole extent thereof. These ramifications frequently unite together, and form as it were a kind of net-work; wherewith the whole *area* of the leaf is filled. Upon pricking one of these nerves, there immediately issues out of the wound plenty of a golden juice, which contains the genuine virtues of the plant celandine; so in the common *aloes*, in the spring-time, we find a yellow, bitter juice lodged in proper ducts for the purpose, and capable of being drawn thence by art: so a wounded poppy emits a pure milky opium. But if these juices be mixed with others of the same plant, there will arise from the mixture something very different from what they are when separate (*d*).

26. Thus much we thought proper to explain concerning the history of plants, before proceeding to shew in what manner they are treated by chemistry: and this may suffice. Hence appears the vanity of those chemists who undertake to exhibit such parts of vegetables separate from the rest, wherein the whole virtue of each plant is lodged. 'Tis certain they must either have some other means for obtaining this end, very different from any hitherto known, or all their endeavours will little avail, except to deceive themselves.

27. With the chemists leave, their distillation, fermentation, putrefaction and calcination make such a change in the peculiar texture of each body, and the medicinal virtues dependant thereon, that the utmost caution must be used before

just as it distils from the tree; the second only differs from this, in that it has been inspissated by the heat of the sun, or fire.

The common colophony is only turpentine, boil'd in water, to a solid consistence. Pills made hereof are what we call turpentine-pills, so much used in the venereal disease, &c.

(*d*) Vegetable bodies are found more uni-

form in respect of their *elements*, than fossils: in the analysis, they all afford *salt*, *water*, *earth* and *sulphur*; but then the salt is of three several sorts, *viz.* acid, urinous, and lixivate*. These principles are all more or less volatile, as a greater or less fire is used: or as the plant has been fermented or not †.

* *Homburg. Mem. de l' Acad. an. 1702.*

† *Id. ib. an. 1701.*

fore the cause of their action can be assigned. It does not hence follow that so noble a science should be rejected, but rather cultivated with the more zeal, as being the only one that shews what may be drawn out of a body by any certain operations, and the only one that detects the failings of its professors: two excellencies which enable it to produce an infinite number of beautiful and useful things. A spiritus rector, or presiding spirit, a sovereign oil, the true seat of this spirit, an acid salt, a neutral salt, an alkaline salt, either fix'd or volatile, an oil mixed with salt after the manner of a soap, and a saponaceous juice hence arising, an oil firmly adhering to the earth, so as scarce to be separable therefrom; and lastly earth it self, the genuine firm basis of all the rest: these are the principles, or matters, which a well-conducted chemistry has hitherto produced from plants (c).

Of

(c) Agreeably to the method hitherto observed, it will be necessary to subjoin a scheme, or division of the several subjects of the vegetable kingdom.

Plants, then, are popularly divided, with respect to *magnitude*, into trees, *arbores*; shrubs, *frutices*; and herbs, or *suffrutices*. Again, with respect to their *food*, and the *element* they live in, plants are divided into *terrestrial*, or *land-plants*; *aquatic* or *water-plants*; and *amphibious*, or those which live indifferently in land or water.

The botanists make more minute distributions: Mr. Ray particularly, distinguishes plants into 25 classes, or genera: viz. 1. *Imperfect plants*, which are such as appear to want the flower and seed, as corals, sponges, &c. 2. *Plants producing an imperfect flower*, and whose seed is too small to be discerned by the naked eye, as fern, polypody, &c. 3. Those whose flowers want petals, as hops, hemp, nettles, docks. 4. Those with a *compound flower*, and which emit a milky juice when cut or broke; as lettuce, dandelion, succory, &c. 5. Those with a *compound flower of a discous form*, and whose seed is wing'd with down; as colts-foot, flea-bane, &c. 6. *Herbæ capitatæ*, or those whose flower is composed of long, fistulous flowers gathered into a round head, and covered with a scaly coat; as the thistle, great burdock, blue-bottle, &c. 7. *Corymbiferous plants* with a discous flower, but no down; as the daisy, yarrow, corn-marygold, &c. 8. *Plants with a perfect flower*, but only one seed to each flower; as valerian, agrimony, burnet, &c. 9. *Umbelliferous plants*, with a flower of five petals, and two seeds to each flower: which being a large genus, is subdivided into seven species; viz. those with a broad flat seed like a leaf, as wild garden-parsnip: with a longish and larger seed, swelling in the middle, as cow-weed, and wild chervil: with a shorter seed, as angelica: with a tu-

berous root, as the earth-nut: with a small striated seed, as caraway, saxifrage, and burnet: with a rough hairy seed, as parslly, wild carrot: with entire leaves undivided into jags, as fenicle, and thorumax. 10. *Stellate plants*, whose leaves grow round the stalks, at certain intervals, in form of stars; as mugweed, madder, &c. 11. *Rough-leav'd plants*, which have their leaves placed alternately, or in no certain order along the stalks; as hounds-tongue, mouse-ear, &c. 12. *Suffrutices* or *verticillate plants*, whose leaves grow by pairs, on their stalks, one leaf right against another; the flower being monopetalous, and usually in form of a helmet: as thyme, mint, pennyroyal, vervain, &c. 13. *Polypermous*, or those with many naked seeds, at least more than four, succeeding their flower, as crow's-foot, marsh-mallows, cinquefoil, strawberries, &c. 14. *Bacciferous plants*, or such as bear berries; as briony, honeysuckle, Solomon's seal, lilly of the valley, nightshade, asparagus, &c. 15. *Multisiliquous* or *corniculate plants*, which after each flower produce several long, slender siliques, or cases wherein their seed is contained; as orpine, navelwort, bears-foots, columbines, &c. 16. *Vasculiferous plants*, or those with a monopetalous flower, and which after each flower have a vessel, beside the calyx, containing the seed; as henbane, bindweed, rampions, fox-glove, eye bright, &c. 17. Those with an uniform tetrapetalous flower, bearing their seeds in oblong siliquous cases, as stock-jillyflower, mustard, radish, &c. 18. *Vasculiferous plants*, with a *seeming tetrapetalous flower*, but of an anomalous, or uncertain kind, and in reality only monopetalous, falling off all together in one, as speedwell, fluellin, plantain, yellow and wild poppy, &c. 19. *Leguminous plants*, or such as bear pulse, with a papilionaceous flower, consisting of four parts, join'd at the edges; as peas, beans, vetches, tares, lentiles, liquorice, trefoil, &c.

Of ANIMALS.

1. The third kind of bodies considered by chemists includes the animal kingdom; we mean the bodies of animals, and the parts thereof: The other principle, *viz.* the mind, being no way the subject of chemical inquiries.

"An animal, therefore, in this sense, may be defined, an hygraulic body which lives by a continual determinate motion of juices in vessels; and containing vascular parts within it self, whereby, as with roots, it imbibes the matter of its nutriment and accretion (f)."

2. The vessels which do this office of roots are found, in almost all known kinds of animals, chiefly seated in the cavity of their small intestines; and known by the names of lacteals and mesenteries. The meat and drink which is brought to the absorbent mouths of these vessels afford the nutrimental matter, and supply the office which the earth does to plants; the cavity therefore of the mouth, gullet, stomach, and small guts, which are in every animal, contribute to the same; and thus plants imbibe their food by external roots, animals by internal ones; and the alimantal earth which is always on the outside of plants, is withinside of animals; which condition even obtains in those kinds of animals that naturally adhere by a strong ligament to some other body, as we find in mussels, oysters, and other *Zoophytes* whose shell grows fast by a callous substance to some adjacent stone, or wood; yet these testaceous covers are regularly nourished, while the animal lives, by certain vessels

Sc. 20. *Vasculiferous plants*, with a *pentapetalous* or *five-headed flower*; as maiden pinks, champions, chickweed, St. John's-wort, flax, primrose, wood-sorrel, &c. 21. Plants with a *true bulbous root*, as garlic, daffodil, hyacinth, saffron, &c. 22. Those whose roots approach nearly to the *bulbous form*, as flower de lys, cuckoo pint, bastard hellebore, &c. 23. *Culmiferous plants*, with a grassy leaf, and an imperfect flower, having a smooth, hollow, jointed stalk, with a long sharp-pointed leaf at each joint, and the seed contained in a chaffy hulk; as wheat, barley, rye, oats, and most kind of grasses. 24. Plants with a grassy leaf, but not culmiferous, with an imperfect, or stameneous flower; as rushes, cat-tail, &c. 25. Plants, whose place of growth is uncertain; chiefly water-plants, as the water-lilly, milk-wort, mouse-tail, &c.

(f) As circumspect as our author has been in framing his definition, there may, perhaps, be animals it does not agree to; and such we take mussels to be. That anomalous creature breathes, and receives its nourishment, not at the mouth, but by the *anus*. The part which we account its *head*, tho' without either eyes, ears, or tongue, or any other apparatus, save a hole, which we call its *mouth*, is an immoveable part; being fasten'd to one of the

shells, so that it cannot go to seek for food, but the food must come to seek it. This food is water, which, as the shells open, enters in at the *anus* of the mussel, which opens at the same time; and passing thence into certain canals between the inner surface of the shell, and the outer surface of the animal, is convey'd thence into its mouth, by a certain motion which the animal can produce at pleasure. From the bottom of the mouth proceeds a sort of intestine, which passing thro' the brain, and making several circumnutations in the liver, traverses the heart, and terminates in the *anus*. Nor does the canal, taken for an intestine, seem proper to carry the food for the nourishment of the parts; since it does not distribute any branches thereto. Add, that it has no veins, or arteries, nor any circulation: and what is yet further surprizing, it is an hermaphrodite; but an hermaphrodite differing from all others of that kind known, as propagating independently of any other animal, and is itself both the father and the mother of its own offspring*.

The ingenious Dr. Tyson fixes the criterion of an animal to be, a *ductus alimentalis*, i. e. a gula, stomach, and intestines, all which make but one continued canal.

* See its anatomy at length in the *Mem. de l'Acad. R. des Scienc.*

appropriated for that office, and from the matter of the body it self; and the animal contained in them receives its nutriment by the mouth, and conveys it to the intestines, like other animals which move at liberty from place to place (g).

(g) Some of our latest naturalists have discovered a progressive motion in several shell-fish, which were reputed to be fixed. M. *Poupart*, in particular, shews that mussels walk on the ground, and some species of them, even tumble along the surface of the water. Their way of walking is thus: lying on the flat of their shells, they thrust out a part, in form of a tongue, which from its use may be called the *arm*: with this they make little motions to the right and left, and by that means dig a passage in the sand or mud of the place. In this digging, they stoop gradually on one side; and so get the shell mounted on edge. This done, they stretch the arm out, as far as they can, for a minute or two; and then rest on its extremity, to draw the shell after them, as water-snails do. Which motion they repeat as long as they mean to walk; thus forming themselves a sort of groove in the sand, which sustains the shell on either side; and leaving behind them a sort of irregular track, three or four yards long. In rivers, &c. that abound in mussels, one sees abundance of these tracks, and a mussel always at the end of them. M. *Poupart* adds, that not having discover'd any muscles, whereby this motion should be effected he supposes that they only stretch out of the shell by imbibing a great quantity of water.

In sea-mussels, M. *Reaumur* has observed, that what we may call the *arm* or *leg*, which in its natural state is not above two lines long, may reach out of the shell above two inches; and the animal having laid hold of some fix'd point, with this arm thus stretch'd out, bends, and shortens it, and thus drags the body after †.

Monf. *Mery*, in his anatomy of the pond-mussel, shews that the whole belly of the animal, when it walks, thrusts out of the shell, in form of the keel of a ship; and that it creeps on its belly, as the serpent does. He even describes the muscles, by whose alternate action the whole mechanism is perform'd ‡.

The *lavignon*, a shell-fish, frequent on the coasts of *Poitou*, of the species of those call'd by the naturalists *chamæ*, or *biatule*, adheres, by its shell, to the bottom; and has a motion

the length of two horns, which it thrusts out of its shell, and therewith receives, and expels the water it needs for respiration. The *goats-eye*, by naturalists called *lepas* and *pattella*, is a shell-fish, of a single piece, always growing to a stone, upon which its lower surface is applied: the only motion it appears to have, is to raise the shell about a line from the stone; and thus leave so much of its body bare to the water: but M. *Reaumur* shews, that it has likewise somewhat of a progressive motion along its stone.

The *sea-nettle* put *Pliny* in doubt to which class of bodies to refer it, plants or animals; but he concludes, after *Aristotle*, to make it of an intermediate kind. Its most usual figure is that of a truncated cone, the larger base whereof is always fasten'd on a stone. The planes of its two bases are circular muscles, and there are recti, or strait muscles, proceeding from one to t'other. All the progressive motion of this animal consists in this, that one half of the muscles of both kinds, which are on the side to which it would move, swells and extends; while the other half, thus weigh'd down, is either drawn after it, or pushes it forward the same way. But the motion here is scarce so swift, or sensible, as that of the hand of a dial-plate. There is another species of sea nettle, which does not grow to any thing; popularly called, and accounted as a *sea-jelly*; which it perfectly resembles, both in colour and consistence: so that if it be held a little in the hand, the single warmth thereof will entirely dissolve it into water. The warmth of a summer's day or two exhales and reduces it almost to nothing; leaving only behind it a thin pellicle, like a fine parchment. What places it in the class of animals, is, that it has a systole and diastole, the only symptom it gives of life ||.

The formation of shells is well accounted for by M. *Reaumur*: before him, naturalists had been contented to suppose the animal, and its shell, to arise from the same egg, and to feed and grow together; but that author gives us other notions. He has found by evident experiment, that the shell, *e. gr.* of garden snails, is form'd of the matter that perspires from the body, hardened after its discharge

* *Mem. de l'Acad. an. 1706.*

† *Mem. de l'Acad. an. 1710.*

‡ *Mem. de l'Acad. 1710.*

|| *Id. ib.*

3. Add, that the foetus of the oviparous kind, lodged and as it were imprisoned in eggs, till by the brooding warmth they become augmented from the *Albumen*, so that quitting the yolk wherein they were before confined, they break their cover, and are set at liberty; as also those whose eggs are laid within the mother's *uterus*, growing thereto by means of *Cotyledons*, or a *Placenta* with an umbilical string: all these at this time, by their *Cotyledons*, *Placenta*, yolk, umbilical string, and *Omphalo-Hepatic* vessels, resemble the plant kind; not but

discharge by the air. 'Tis certain, that all animals do also perspire, and are surrounded with a sort of cloud, or atmosphere, exhaled from them, and which 'tis probable assumes somewhat of this external figure: and what snails have peculiar to them, is, that the atmosphere of their perspiration condenses and hardens around them, and forms them a visible cover, whereof their body is, as it were, the core; whereas, what other animals perspire, evaporates, and loses itself in air. This difference arises from the different substance transpired; that from snails, &c. being viscid, and cretaceous, as M. *Reaumur* finds by experiment.

On this principle, though the shell do the office of an universal bone, it does not grow like a bone, nor like the other parts of an animal, by intro-susception, that is, by a juice circulating within itself; but by *juxta-position*, i. e. an external addition of parts, over one another; as stones are usually supposed to grow. And it is worth observing, that there is an animal substance which grows after the manner of fossils.

To be a little more explicit: it must be remembered that the head of a snail is always next the aperture of the shell, and its tail towards the point or apex thereof; and that its body, from some cause or other, naturally forms itself into a spiral, the different turns or circumsolutions whereof, are in different planes. This supposed, take a snail just hatch'd, and in its first littleness; since the matter it perspires petrifies around it, it must first have a little cover, proportional to the bigness of its body; and as its body is yet too little to make a turn of one spiral, at a whole turn; this cover will only be the centre, or, as it were, the beginning of a little turn of a spiral. But the animal continues growing: if it ceased withal to transpire, 'tis evident that so much as it should be increased by, would remain naked: but as it continues to transpire, it makes itself a new covering, in proportion as it grows, which new cover is added at the extremity of the first; and if the snail have grown to make a second spiral turn, the shell also makes a se-

cond: at the same time, the animal has likewise grown in thickness, so that this second turn, is bigger than the first. The rest go on in the same manner: and in an ordinary garden-snail there may be some four or five such circumsolutions.

Hence we see why the first turns of a young snail, which, for instance, has only form'd two, are as big as those same turns of an older snail; for what is once form'd of a shell, does not grow any further, except in thickness: and accordingly, tho' the first circumsolutions of a young snail's shell be as long and broad as those of an old one, they are not so thick*.

M. *Mery* objects, that tho' this formation may hold in the shells of snails, yet it does not in the shells of mussels: for 1. These shells are visibly composed of several laminæ, or leaves, which standing out beyond each other, form distinct bands, or zones, on the outer surface thereof; and the little shells are found to have as many of these bands, as the greatest: whence it follows, that mussel-shells grow like the other parts of animals, which, how little soever they be, do always consist of the same number of parts. 2. Add, that the bands in the shell of a little mussel, are less than in a large one; and of consequence must grow as the animal does, and in the same manner. 3. A mussel has eight little muscles, fastened in the inner surface of its two shells: now if the shells did not grow in the same manner as the fish, it would follow, that those which at first were fastened in certain parts of the young mussel, must be continually changing their place of fastening, to the utmost growth of the animal; which scarce seems possible, and has no parallel in any animal known †.

But M. *Reaumur* vindicates his system from all these objections: to the two first he answers, that there are sometimes even more bands in a lesser mussel-shell than a greater; but that this does not argue either intro-susception or juxtaposition; being intirely owing to this, that the distinction of the bands is liable to be disturbed, and two to be made appear as only one, by the edges of the laminæ, that lap over, being

* *Mem. de l'Acad. R. des Scienc. an. 1709.*

† *Mem. de l'Acad. an. 1710.*

but they receive food by the mouth from the reservoir of the *Amnios*, and convey it to the intestines, and are sustained after the manner of others (*b*).

4. There appears therefore a wonderful conformity as well as diversity, between vegetables and animals. — Hence, as some plants grow fixed in the ground, others float on the water, and others live indifferently in either place; so it is in animals, some of which are terrestrial, others aquatic, and others amphibious: and as plants by the absorbent vessels of their bark imbibe moisture from the air, so do animals.

5. A great agreement also appears between them, upon considering that they are both sustained with the same food. As plants consist of a juice drawn from the earth, so are animals fed with vegetables, or other parts of animals, which themselves were fed with the juices of plants; so that the matter is the same in both.

6. And as the juice which vegetables imbibe from the ground by the absorbent vessels in their roots, is crude, and not yet reduced to a vegetable nature; so the food and chyle formed thereof, is not yet of the nature of the animal fed with it; but long retains that of the subject whence it was taken.

7. Hence it is gradually changed by the organical structure of the animal, and the mixture of concocted juices therein, into various other forms and new kinds in every different part of the body; as will be explained more at large elsewhere: it may suffice for the present purpose to observe, that the food continually recedes the further from its own nature, and approaches nearer to the properties of the animal it is found in, the longer it is circulated thro' all parts of the body, and mixed with a greater variety of its juices.

8. The most subtile part of the juices of animals is a fine spirit, which is continually exhaling, wherein the proper character of the animal seems to reside, and whereby it is distinguished from all others. This we may infer from hounds, which thro' a long tract of ground, and a multitude of cross treads, will distinguish a particular animal out of a whole flock, the *effluvia* of whose footsteps it had lately scented, or will find out their master thro' an hundred cross ways in the middle of a confused concourse of people. By this we may infer how thin and subtile, yet how different from all other kinds of bodies these *effluvia* must be. They seem of an oily origin, or to reside in a subtile vehicle of an oily kind; as may appear both from the analogy of things and other properties.

Spirits in animals.

Water,

being broke or wore down, by the attrition of the sand, sea-water, &c. The third difficulty he obviates by a parallel case: crabs, lobsters, &c. are covered with an external crust, or shell; and have muscles or ligaments, wherewith they are fastened on the inside thereof: and yet they cast their shells every year; and take new ones: notwithstanding which, they are always found fast tyed in their shells, and never loose therein. Consequently their muscles or ligaments must be transferred from the old crust to the new: and the mechanism whereby that is effected, may be applied to mussels*.

(*b*) "How the foetus is nourished in the womb, Dr. Drake observes, is a question as much agitated among anatomists as any whatever: some contend that it is nourished by the mouth; others will have it receive its increase, and grow like a vegetable, from the mother as from the root, of which the umbilical vessels are the stem, and the child the head or fruit†." Were it not for that small share of muscular motion, which the foetus exercise in the womb, it might without absurdity be accounted as a graft upon a branch of the mother‡.

* *Mém. de l'Acad. an. 1716.*

† *Antropol. l. 1. c. 22.*

‡ *Id. ib. l. 2. c. 7.*

Water.

9. Water, which affords the chief matter of most other bodies, does the same in respect of the humours of animals, and is so intimately mixed with all, even the most solid parts of animal bodies, that there is scarce any entirely without it; as chemists have long ago discovered.

Salt.

10. They contain a salt peculiar to each animal, beside those other salts which they receive from without, and are not altered by the habit of the body.

11. But this salt is never found fix'd; nor is it yet so volatile, as to exhale by the greatest heat an animal is capable of, while in a state of health. Yet a fire, somewhat stronger than that of boiling water, by long application volatilizes the whole of it.

12. Nor has this ever been found of an acid kind, except where it was occasioned by some acidity in the aliment. Nor has it by any experiment been found to have been alkaline, either in sound, or even in diseased animals. I have examined the urine of a person, which by reason of an ischuria, had been detained five days in his body, yet found not any thing alkaline therein.

13. But this same salt either by means of putrefaction, or of a vehement fire, may be rendered wholly alkaline: but when by a careful process, it is formed into glebes, which is only done by inspissation and leaving it to rest, it is found different from all the hitherto known kinds of salts; and approaches nearest to the nature of *sal-ammoniac*, from which, notwithstanding, it differs in several respects; since the latter, when exposed to a strong fire, sublimes in its whole substance, without being changed; whereas the former being extracted from urine, the proper *Lixivium* of animal salts, presently becomes alkaline in its whole substance.

14. In fine, after a multitude of experiments which I have made to determine the true nature of animal salt, as it is found in the bodies of healthy animals, and there exerts its natural power; it appears to be mild, saponaceous, formed of a concrete oil, of an intermediate nature between those called volatile and fixed salts, having none of the characters either of an alkali, or an acid; easy to be resolved into a fetid, volatile oil, and alkaline salt, and accordingly much disposed to putrefy. Nor let any one be led into an error by finding a fix'd salt in the lye of burnt animal-ashes; this being only the effect of the sea-salt which had been taken into the body, and had undergone all the actions and operations thereof, without changing its nature, or being assimilated with the animal substance. To the same origin we may attribute that little acidity obtained with much labour, and the utmost torture of the fire from human blood; which seems only to be an acid spirit of sea-salt mix'd with earth, and violently agitated by the fire: and hence, animals which make no use of sea-salt in their food, of necessity have no fix'd salt in their urine, or acid in their blood.

Animal oils.

15. The oils of animals examined by chemistry, are found very different; some, being so subtile as to be miscible with water, and volatile by a gentle heat, bear a resemblance to the vegetable spirits produced by fermentation, which however they are very different from. Others are found extremely mild, destitute of almost all salt, being using for anointing, smearing, and suppling

pling the solid parts. Some of these being lodged in the cavities of the bones, are called marrow; others placed in the *Membrana adiposa* are called fat, where it is reserved for its proper use; which is to correct the acrimonious juices of the body: and they are sometimes found swimming on the blood.

16. Another species of oil different from the former, is that which cohering with the salts of animals, renders them saponaceous and suitable to the body: this, when separated, is sharper, more fetid and volatile, than any of the former.

17. Another oil is that which joins the elements of the solid parts into firm substances, yet so as to preserve the necessary flexibility. This grows up with the earthy elements, and is scarce separable therefrom, except by a violent fire, or being long exposed to the action of air, water and hear, which putrefying it, makes it let go the volatile matter of the oil, leaving only some incoherent ashes; as we find by the very fetid smell arising therefrom.

18. Another oil of an extraordinary kind, is that expressed from the juices of animals, by inspissating and then exposing them to a long and violent heat: This is known by the name of *Phosphorus*, and consists of a substance which spontaneously takes fire in the open air, and burns away to an acid, fix'd, humid matter.

19. Lastly, the basis of the body, and that upon which the rest are fastened, and whereby the humors are retained, is earth. This appears the same in animals as in vegetables, as may be learnt from the tests and muffles wherein the assayers prove their metals. The only terrestrial matter fit to make these of, is a very simple kind of earth, not fusible in fire, nor capable of running into glass; but the same may likewise be made, equally fit for the purpose, of the pure calx of burnt vegetables, or animals, well cleansed from the ashes of any other fuel which may happen to be mixed with it. Nor do the earthy parts thus produced appear to differ in any respect from one another.

20. Such are the elements which occur in the structure of animal bodies; art discovers and exhibits no more nor greater diversities. But it is in vain to expect that by carefully separating these, and artfully mixing them again, we should re-produce the natural humors from whence they were obtain'd. On the contrary, by such mixture we should produce compounds very different from the primitive ones; for in each part of an animal we find humors of a peculiar kind, which always appear specifically different from one another. In one place the bitter bile is found, in another the hepatic; the seminal juice is only found in its proper receptacle; the moving spirits are generated in another place; the chyle is different, according to the different parts of the body, as the stomach, intestines, mesentery, *Ductus Chyliferi*, *Vena cava*, heart, lungs, arteries, &c. and the like may be said of the humors secreted from it, as the milk, fat, lymph, serum, saliva, blood, urine, and the like.

21. Upon the whole, we may discover a near resemblance between the elements of plants and animals, which latter are made up of the same matter with vegetables: the chief difference consists in the variety of their structure, and the quicker passage of the aliment through the bodies of animals, than of plants. And thus much may suffice for the object of chemistry (i).

(i) "Animals afford the same elements, by a chemical analysis, as vegetables; viz. salt, sulphur, earth, and water; with this difference, that the salt of vegetables is of three sorts, and that of animals only of two, viz. urinous and lixivate, without any manifest acid." *Homburg. Mem. de l'Acad. R. an. 1702.*



OF

OF THE OPERATIONS OF CHEMISTRY.

1. CHEMISTRY is employed in changing the bodies contained in the three classes above specify'd, and the change it produces in them is effected by means of motion alone (k).

Motion

(k) Motion, thus, being the means whereby chemistry operates; the doctrine of motion, *i. e. mechanics*, becomes the key, whereby its operations are to be accounted for. So far, then, as we know of the nature, and laws of motion; so much we may conceive of the means whereby a chemical effect is produced. But our knowledge here, is in reality very scanty, and confined to narrow bounds: many of the laws of motion, percussion, &c. in sensible bodies, under various circumstances, as falling, projected, &c. are well ascertained by the later philosophers; but these will not reach to those more remote, intestine motions of the component particles of the same bodies whereon the changes of texture, colour, properties, &c. induced by chemistry, depend. Beside the common laws of sensible masses, the minute parts they are composed of, seem subject to some others, which have been but lately taken notice of, and are yet little more than guessed at. Sir I. Newton, to whose happy penetration we owe the hint, contents himself to establish, that there are such motions in the *minima natura*, and that they flow from certain powers, or forces not reducible to any of those in the great world. In virtue of these powers, he shews, that the small particles of bodies act on one another even at a distance; and that many of the phenomena of nature are the result hereof. Even sensible bodies, we know, act on one another divers ways; as by gravity, magnetism, and electricity, which are directed by different laws: and as we thus perceive the

tenor and course of nature, it will appear highly probable, there may be other powers. Those just mentioned, reach to sensible distances, and so have been observed by vulgar eyes: but there may be others, which reach to such small distances, as have hitherto escaped observation; and 'tis probable electricity may reach to such distances, even without being excited by friction.

The great author just mention'd, proceeds to confirm the reality of these suspicions from a great number of phenomena, and experiments, which plainly argue such powers and actions between the particles, *e. gr.* of salts and water, oil of vitriol and water, *aqua fortis* and iron, spirit of vitriol and salt-petre. He also shews, that these powers, &c. are unequally strong between different bodies, between the particles of salt of tartar, or greater, for instance, and those of *aqua fortis*, than those of silver; between *aqua fortis* and *lapis calaminaris*, than iron; iron more than copper, copper more than silver or mercury. So, spirit of vitriol acts on water, but more on iron or copper, &c.

These actions, in virtue whereof the particles of the bodies abovementioned tend toward each other, the author calls by a general, indefinite name, *attraction*; which is equally applicable to all actions whereby bodies tend towards one another, whether in virtue of their weight, magnetism, electricity, impulse, or any other more latent power; for 'tis not the cause determining the bodies to approach, that he expresses by this name;

2. Motion then may either be excited a-new ; or be suppressed when already raised ; or be changed in its degree, by increasing or diminishing it ; or the quantity of it may remain the same ; or only its course and direction be changed ; which changes again are sometimes of the whole substance, and sometimes only of some of the constituent particles whereof it is composed. From these few simple actions therefore, all the effects of chemistry must arise ; tho' by reason of the numerous, different kinds of corpuscles subject to them, there results a vast variety of new and wonderful facts, cases and appearances : yet if we consider the thing closely, it will evidently appear whence they all arise, and that the art has no other to work by. Suppose, for instance, a single corporeal mass wholly at rest ; that is, all its particles mutually quiescent among themselves, such as it was at the beginning, must it not remain the same and unchanged in all future times ? Though the whole power of chemistry were applied to it, yet if it raise no motion in any of its parts, it must remain as it did ; or suppose a motion communicated to the whole mass, whereby it is removed to another place, without making any further change in the constituent parts of the body, the idea of such body will still remain the same ; with this only difference, that the situation of it is changed every instant. But if a motion be raised among the parts, we may conceive an inexhaustible variety of effects and changes producible therefrom. Chemistry then, is totally employ'd, either in uniting, or in separating ; there being no third operation in nature : so that to these are all its multitude of operations reducible, without one exception.

3. Let no one object against this simplicity, as if it were impossible that so many and such different productions, and which are attended with such surprising and singular effects, should arise herefrom : for it is well known that the more simple, mechanical applications of different things, produce the utmost va-

riety of effects, i. e. the approach : the cause he has no regard to, till such time as the effect is well ascertain'd. In his philosophy, the research into causes is the last thing ; and never comes in turn, till the laws and phenomena of the effect be settled : it being to these phenomena that the cause is to be accommodated. But the cause even of any the grossest and most sensible of these actions, is not adequately known : how impulse itself works its effect, would confound the deepest philosopher ; yet is impulse received into mathematics, and the laws and phenomena of its effects, make the greatest part of the common mechanics. The other species of attractions, therefore, when their phenomena are sufficiently ascertain'd, have the same title to be promoted from physical to mathematical consideration ; and this without any previous inquiry into their causes, which our conceptions may not be proportionate to : let their causes be occult, as all causes perhaps ever will be ; so as their effects, which alone immediately concern us, be but apparent. Our noble country-

man, then, far from adulterating philosophy with any thing foreign or metaphysical, as some have reproach'd him : has the glory of opening a new source of sublimer mechanics ; which, duly cultivated might be of infinitely more extent than all the mechanics yet known. 'Tis hence alone we must expect to learn the manner of the changes, productions, generations, corruptions, &c. of natural things ; which are the great object of that part of philosophy called chemistry.

Some of our own countrymen have prosecuted the discovery with laudable zeal ; Dr. Keill, particularly, has endeavour'd to deduce some of the laws of this new action ; and applied them to solve some of the more general phenomena of bodies, as cohesion, fluidity, elasticity, softness, fermentation, coagulation, &c. And Dr. Freind, seconding him, has made a further application of the same principles, to account, at once, for almost all the phenomena that chemistry presents. So that the new mechanics should seem already raised to a compleat science : and that nothing can now

turn.

riety in their compounds; and that a multitude of new bodies may arise from a few elements, is demonstrated by arithmeticians in the doctrine of combinations. Add, that by the apposition of one body to another, some latent virtue frequently discovers itself. Thus if a load-stone had never been placed so near another as to be within the sphere of its attraction, it would have been yet unknown that there is such a thing as magnetism in nature: and if iron had never been applied to the same stone, that extraordinary agreement between the load-stone and iron had been yet undiscovered. Lastly, if iron touch'd with the load-stone had never been applied to other iron, either touch'd or not touch'd with the same, who would have dreamt of those hidden powers which here produce such singular effects. It also appears in the history of menstruums, that multitudes of bodies have certain relative powers, which only shew themselves upon placing them near one another. From the whole it follows, that by separating compounds into their simples, and mixing simples with simples, an infinite number of things before unknown may be produced. If we only consider a single body retaining the same bulk, but only changed in its figure, that is in the disposition of its surface, yet we shall find it capable of exerting very different powers. Thus in mechanics, the same piece of steel according to the different figure which is given it, will produce instruments of very different powers; as a wedge, knife, poinard, lancet, sphere, cube, cylinder, prism, pyramid, cone, &c. From all which it appears, that the simplicity of chemical operations does not hinder, but that infinite, different effects may be produced thereby.

4. The consideration of this is of great importance in the art: there being a kind of presumption among chemists, as if there was some mystery in their art; whereas if the chief operations be considered, the truth of what is above-mentioned will appear: such are calcination, fixation, vitrification, sublimation, fermentation, putrefaction, digestion, purification, union, and all the other

turn up, but we have an immediate solution of, from the attractive force.

But this seems a little too precipitate; a principle, so fertile, should have been further exhausted; its particular laws, limits, &c. more industriously detected, and laid down, before we had gone to application. Attraction, in the gross, is so complex a thing, that it may solve a thousand different things alike: the notion is but one degree more simple, and precise, than action itself: and till more of its properties are ascertained, it were better to apply it less, and study it more.

All the phenomena, all the changes in the universe, are the effects of motion. Accordingly, to have a succession of such changes, the author of nature has added to bodies certain active principles to be the sources of motion.—Nature, says Sir I. Newton, performs all the great motions of the heavenly bodies by the attraction of gravity, which intercedes those bodies; and almost all the small ones of their particles, by some other attractive, and repelling powers which intercede the par-

ticles. Body it self is merely passive, and needed some other principle to move it; and now that it is in motion, it needs some other principle for conserving that motion. By the tenacity of fluids, the attrition of their parts, and the weakness of elasticity in solids, the motion which we find in the world, is always dwindling, and on the decay; so that there arises a necessity of recruiting it by active principles: such are the cause of gravity, by which the planets and comets keep their motions in their orbs, and bodies acquire motion in falling; and such the cause of fermentation, by which the heart and blood of animals are kept in perpetual motion, the inward parts of the earth are constantly warm'd; bodies burn and shine, mountains take fire, caverns blown up, &c. For we see but little motion in the world, beside what is owing to these active principles: And were it not for these, the bodies of the earth, planets, comets, sun, and all things in them, would grow cold, and freeze, and become unactive masses. *Optic*, p. 373, and 375.

other operations. But a separation of parts thus effected, does not shew that those parts had pre-existed in the body, such as they now appear; since those very operations whereby the parts become separated and disengaged from the rest, may make great alterations in them: so that it is a false conclusion of the generality of chemists, that their elements were really contained in the compounds. Add, that bodies when de-compounded, acquire new powers, which they had never exerted before; of which we have innumerable instances.

5. On both these accounts it is by no means so clear as chemists imagine, that their art gives the true first elements of things; and that we may judge of the compounds by the principles into which they are chemically resolvable (*l*).

6. From

(*l*) Thus the great *English* philosopher: All bodies seem to be composed of hard particles: for all bodies, so far as experience reaches, are either hard of themselves, or may be rendered hard; *viz.* some by freezing, as waters, oils, &c. others, as mercury, by fumes of lead; and spirits of wine, and urine, by dephlegmating and mixing them: even the rays of light themselves are hard bodies, as appears from their retaining different properties in their different sides. Many compound bodies are very hard, notwithstanding that they are very porous, and consist of parts that are only laid together: How much harder then must the simple particles, or atoms themselves be, which are entirely devoid of all pores? And how such particles, by only laying them together, and touching in a few points, should cohere, and so firmly, without the intervention of something that attracts, or perhaps even presses them together, can scarce be conceived. These simple, or smallest particles cohering by the strongest force or attraction, compose bigger particles of feebler virtue; and many of these cohering, compose other particles still bigger, and more weakly united: and so on for divers successions; till the progression end in the biggest particles, on which the colours of natural bodies, and the operations in chemistry depend; which, by cohering, compose masses, or bodies of a sensible magnitude*.

Elements or *principles* are defined by M. *Homburg* to be the most simple matters into which a mixed body is reducible by chemical analyses: but the chemists do few of them use the word with so much reserve: chusing rather to conceive, and speak of *elements*, as the very primary corpuscles whereof mixt bodies are composed: a way of conceiving, which subjects them to infinite difficulties, and is the foundation of a good part of the objections made against them by Mr. *Boyle*.

The ancient chemists allow but of three elements; *viz.* salt, sulphur, and mercury; which they more emphatically call *hypostatical principles*, or the *tria prima*. To which the moderns have added two more, *viz.* water and earth.

These principles took their denomination from certain qualities observed in the several substances procured in analysing of bodies by fire: an inflammable substance rising, that would not mix with water, they call *sulphur*: what comes over sapid, and dissoluble in water, passes for *salt*: what is fixed, and indissoluble in water, they name *earth*: and all the volatile substances, *mercuries*. Or thus,

A body, in distillation, usually separates into volatile and fixed parts; and these volatile parts either ascend in a dry form, which, if it be sapid, they call *volatile salt*: or in a liquid form; which liquor is either inflammable, and so passes for *sulphur*, or *oil*; or not inflammable, and yet subtle and pungent, called *mercury*, or *spirit*; or else insipid, term'd *phlegm*, or *water*: for the fixed part, it usually consists of particles, partly soluble in water, and sapid; which therefore make *fixed salt*; and partly insoluble and insipid, called *earth*.

The distinct offices of each in the composition of bodies, they thus assign: salt is the basis of solidity and permanency; that this may be dissolved into minute parts, and convey'd to the other elements, there is a necessity of water: and that the mixture may not be too rigid, and brittle, a sulphurous or oily principle must intervene, to make the mass more tenacious: To this a mercurial spirit must be superadded, which, by its activity, may permeate, and, as it were, leaven the whole mass, and thereby promote the more exquisite incorporation of the ingredients. To all these a portion of earth must be join'd, which, by its dryness and porosity, may soak up

* *Newton. Optic.* p. 364, and 370.

6. From a near consideration of things it appears, that there are corpuscles, which when alone, are unchangeable by any cause hitherto observed; being

endued up part of the water wherein the salt was dissolved, and concur with the other ingredients, to give the body the requisite resistance.

These principles are usually divided into *active* and *passive*; the active are the *tria prima*, or three hypothetical principles; the passive are earth and water, which are also called *elementary* principles. But M. Homberg has reform'd this division: sulphur he makes the only *active* principle; earth the only *passive* one; and all the rest *intermediate* principles. Sulphur is the active principle, in regard, according to him, 'tis this alone that acts of itself, and that makes all the rest act. Earth is denominated a passive principle, as it never acts, but serves merely as a matrix or receptacle of the other principles. And salt, water, and mercury, are called *intermediate principles*, because they do not act of themselves, and yet become capable of acting, by their being join'd with sulphur, which modifies them, and is modified by them a thousand ways*.

Mr. Boyle attacks the common doctrine of the chemical elements, with admirable force and address; making appear, that the different substances into which mix'd bodies are commonly resolved by fire, are not of a pure and elementary nature; but retain so much of the concrete that afforded them, as to appear still compounded; and often to differ in one concrete from principles of the same denomination in another: that, as to their number, it is not precisely three, as the chemists have usually maintain'd; because in most vegetable and animal bodies, earth and phlegm are also found; but that there is no one determinate number into which the fire universally resolves all compounds, mineral and others: And that there are several qualities which cannot be refer'd to any of these substances, as if they primarily resided therein; there being withal other qualities, which tho' they seem to have their chief and most ordinary residence in one or other of these principles, are not yet so deducible from it, but that more general principles may be taken in†.

It may be alledged, that bodies are only called salt, sulphur, mercury, &c. on this footing, that the principle of the same is predominant therein; but it does not even appear, that the reputed salt, sulphur, or mercury, principally consists of one simple body, to give it that denomination; or that there is any such primitive simple substances exist-

ing in the bodies whence these are procured. If it be demanded then, what is it that the chemical analyses do prove? We answer, that mixed bodies included in close vessels, are resolvable into several substances different in some qualities, but chiefly in consistence: so that out of most bodies may be obtain'd a fixed substance, partly saline, and partly insipid; an unctuous liquor, and another fluid, or more, which, without being unctuous, have manifest taste. Now, if the chemists will agree to call the dry and sapid substance, *salt*; the unctuous liquor, *sulphur*; and the other *mercury*; we have nothing to object: But if they will obtrude this salt, sulphur, and mercury on us, as simple and primary substances, whereof each mix'd is actually compounded, and which were really therein antecedent to the operations of fire; they go further than their experiments will bear them out. And as an element ought to be perfectly similar, and homogeneous; there is no just cause why we should give a body proposed the name of any particular element or principle, because it bears a resemblance thereto in some obvious quality, rather than deny it that name on account of several other qualities, wherein it is unlike‡.

The chemists will not allow the salt in ashes to be called *earth*; notwithstanding that the saline and earthy parts correspond in many respects; *e. gr.* weight, dryness, fixedness, and fusibility; for this only reason, that the one is sapid, and dissoluble in water, and the other not: beside, that sapidness and volatility denominate the chemists *spirit* or *mercury*. And yet, how many bodies may happen to agree in those qualities, which have different natures, and divers disagreeing qualities?

For not only spirit of nitre, *aqua fortis*, spirit of salt, oil of vitriol, spirit of alum, spirit of vinegar, and all saline liquors distill'd from animals; but all acetous spirits of woods, must belong to their mercury; tho' it does not appear why some of these should rather come under that denomination, than the chemists sulphur or oil; for their distill'd oils are fluid, volatile, and sapid, as well as their mercuries. Nor is it necessary that sulphur should be unctuous, or indissoluble in water; since spirit of wine is generally refer'd to sulphurs, tho' it be not unctuous, and will readily mix with water. So that nothing but bare inflammability is left to constitute the essence of the chemists *sulphur*; as the contrary, join'd with any taste, entitles a distill'd liquor

* Mem. de l'Acad. an. 1702.

† See: s. Chym.

‡ Boyle, ubi supra.

endued by the author of nature with such a degree either of hardness, as that they are incapable of being divided into less parcels, or being changed in their figures;

liquor to their *mercury*. Now, since spirit of nitre, and spirit of hart's-horn will bubble together, hiss, and throw up one another into the air, which the chemists allow for indications of great contrarieties in bodies; since we may obtain two sorts of oil from the same parcel of human blood, which will not mix with one another; and since we meet with numerous instances of other contrarieties in bodies, which, according to the chemists, must be huddled up together, under one denomination: It may be worth considering how far such a multitude of substances, as may agree in these slight qualities, and yet disagree in others, deserve to be called by the same name of a principle, rather than have such appellations as distinguish them from bodies they differ so much from.—When unable to shew that a liquor is, for example, purely saline; they prove, that at least salt is the predominant principle therein, from this consideration, that it is strongly tasted; and that all taste proceeds from salt: whereas spirits, as of tartar, hart's-horn, &c. which are reputed the mercuries of the bodies that afford them, have manifestly a strong and piercing taste. And indeed, if taste belong not to the spirit, or mercurial principle of vegetables, and animals; we scarce know how it will be distinguished from their phlegm; since, by the absence of inflammability, it must be distinguished from sulphur. Add, that not only the spirits of vegetables, but their oils, are very strongly tasted; and the most elaborate depuration will scarce ever reach to make them tasteless.—Again, volatile salt of hart's-horn, &c. is very strongly scented, notwithstanding that most chemists deduce odours from sulphur, and from them argue the predominancy of that principle in the odorous body.—From the whole, it appears how dissimilar each of those bodies are, which the chemists call the salts, sulphurs, or mercuries of the bodies which yield them; as if they had all a simplicity or identity of nature: whereas salts, for instance, if they were all elementary, would differ as little as the drops of pure and simple water: So that we have no positive knowledge of the chemical principle sulphur, by means of analyses, or the decomposing of mixts. This led M. *Homborg* to imagine, that something might be learn'd of it from compositions, or artificial mixts: The effect of a great number of operations of which kind, gave him indications, that 'tis light or fire is

the real principle sulphur, and the only active matter in all mixts. So that we must refer the disquisition into the nature, properties, &c. of sulphur, to the article of fire.

Indeed it should be express'd what kind of division by fire is to determine the number of elements; for the same body, *e. gr. guaiacum*, which, burnt in an open fire, only resolves into two, *viz.* ashes and soot; if distill'd in a retort, resolves into oil, spirit, vinegar, water, and charcoal; the last of which, by a farther degree of fire, in an open vessel, falls into ashes, *i. e.* into salt and earth; and by a farther yet, into glass. If then oil passes for an element, because producible by one degree of fire; why is not glass? There are some mix'd bodies, from which it does not appear that any degree of fire will separate any of the common elements; such is gold, and perhaps also silver, *Venetian* talc, osteocolla, and glass; which, tho' made of a pure colliquation of the salt and earth remaining in the ashes of a burnt plant, yet will so far resist the violence of fire, that it has been held more irreducible than gold: But if an artificer can unite such comparatively gross particles, as those of earth and salt, into a body indissoluble by fire; why may not nature associate in several bodies the more minute elementary corpuscles, too firmly to let them be parted by fire? There are some bodies whose component principles are so minute, and so firmly united, that their corpuscles need less heat to carry them up, and dissipate them, than is requisite to divide them into their principles. And hence it is, that the common sulphur becomes so difficult to decompose.

We have no evidence, that three is precisely and universally the number of the distinct substances or elements, into which all mixed bodies are resolvable by fire: If it be granted, that the elements at first consisted of certain small primary coalitions of the minute atoms, or particles of matter, into corpuscles very numerous, and like each other; it will rather appear, that such primary masses may be of far more sorts than three, or five; and consequently we need not suppose that in every compound body there should be found just three sorts of such primitive coalitions. It is impossible but that two sorts of elementary bodies may suffice; as we see is the case in that durable substance, glass: while others consist of three, another of four, another of five, &c. Nay, it does not seem impossible, but

but there may be two, or more sorts of mixts, which have none of the same elements as the other: as we often see two words, whereof the one has not any of the letters in the other; or, as happens in electuaries, wherein no ingredient, except sugar, is common to any two of them. And this is confirm'd by chemical experiments: For as from some bodies, *e. gr.* gold, even three principles cannot be procured; so from others, *e. gr.* grapes, variously managed, may be procured at least a dozen.

Fire, even when it does divide a body into substances of various consistences, does not commonly analyse it into hypostatical principles; but only disposes its parts into new textures, and thereby produces concretes of a new, indeed, but of a compound nature: and there are many distinct substances obtainable from some concretes without fire, which no less deserve the denomination of elementary than those extorted by fire. In reality, different degrees of fixity and volatility seem to have a great effect in the producing of different elements. For, that fire frequently divides bodies on this only account, that some of their particles are more fixed than others, tho' either of the two be all the while far from pure and elementary, is obvious in the burning of wood, which the fire separates into smoke and ashes; the former of which, confessedly consists of two such different bodies as earth and salt; and the latter, condensed into soot, discovers itself to contain salt, oil, spirit, earth, and phlegm; all which being almost equally volatile in that degree of fire which forces them up, are carried away together. Beside, if two different bodies, united into one mass, be both sufficiently fixed; the fire finding no parts volatile enough to be carried up, makes no separation at all*.

It does not appear that all mixts are of elementary bodies; but rather, that there are several compounds even in regard of their ingredients consider'd antecedently to their mixture: for tho' some may be made up of the immediate coalitions of the elements, or principles themselves; yet others are mix'd at second hand: now if a compound consists of ingredients not merely elementary; 'tis easy to conceive, that the substances into which fire resolves it, tho' seemingly homogeneous, may be of a compound nature; those parts of each body that are most akin, associating themselves into a compound of a new kind. Thus, out of distill'd liquors, which are reputed the elements of the bodies whence they are drawn, *viz.* oil of vitriol, and oil of tur-

pentine; the same author, without any addition, procured a third, *viz.* a true, yellow, inflammable sulphur; the two liquors afterwards remaining distinct: and from the spirit of box-wood, highly rectified, he procured an acid liquor, that would dissolve coral; leaving a spirit of a very different nature from the common spirit of that wood: so that at least some of the elements are far from an elementary simplicity; and may be still look'd upon as mix'd bodies. Add, that as there may be more elements than five or six; so the elements of one body may be different from those of another: whence it follows, that from the resolution of compound bodies, there may result mixtures, wholly of a new kind, by the coalition of elements, perhaps never convenied before†.

Helmont gives us a way of converting oil of cinnamon, blood, hart's-horn, or the like, wholly into volatile salts, by a bare mixture of their own alkaline salts: if, then, such saline volatile substances, which pass for elementary, be producible of chemical oils, and fix'd salts, the one made volatile by the other, and both associated by the fire; it may well be suspected, that other substances, arising from the separation of bodies by fire; may be new sorts of mixtures, and consist of ingredients of different natures. Thus, particularly, it is to be suspected, that since the volatile salts of blood, hart's-horn, &c. are fugitive, and of an exceeding strong smell; 'tis either an error to ascribe all odours to sulphurs; or that such salts consist of some oily parts, well incorporated with the saline ones: and the like conjecture may be also made, as to spirit of vinegar, which has a piercing smell‡.

That phlegm is not an elementary body, appears from its different powers and properties: the phlegm of wine, and most liquors, have qualities, that make them differ both from mere water, and from one another: the phlegm of vitriol, Mr. Boyle observes, is an effectual remedy against burns; and a valuable nostrum for dissolving hard tumors: that of vinegar will extract a saccharine sweetness out of lead, and even dissolve corals with long digestion: that of sugar of lead is said to dissolve pearls||.

The characters which serve to denominate a fluid phlegm, or water, among the chemists, are insipidity, and volatility; yet quicksilver has both these, which no body pretends to be phlegm. Add, that it appears from several experiments, that water itself, by repeated distillations may possibly be converted into earth**.

* Boyle ubi supra. † Ib.
** Boyle's Producib. of Chym. Princip.

† Id. ibid.

Y Water
|| Scapt. Chym.

Water has a much fairer pretence to be an element, than any of the *tria prima*: the chief qualities that occasion men to give that name to any visible substance, are, that it is fluid, insipid, and inodorous: but we have never seen any of those separated substances which chemists call phlegm, perfectly destitute both of taste and smell. Common salt, and several other saline bodies distilled ever so dry, will each yield a large quantity of phlegm; which can be no other way accounted for, but from this, that among the various operations of the fire, on the matter of a concrete, several particles of the matter are reduced to a shape and size, requisite to compose such a liquor as the chemists call phlegm or water*. See farther in the article of *Water*.

The name *spirit* is applied by the chemists to several very different substances: it denotes in the general, any distilled, volatile liquor, that is not insipid as phlegm, nor inflammable as oil: but under this general idea are comprehended liquors of quite opposite natures, some being *acid*, as the spirits of nitre, salt, and vinegar; and others *alkalious*, which are such enemies to the former, that as soon as they are put together, they tumultuate and grow hot: To which may be added, a third kind, called *vinous*, or inflammable; which, tho' very subtle and penetrating, are not manifestly either acid or alkaline.

All these sorts of spirits Mr. Boyle shews to be producible: and, 1. The *vinous*, which nature scarce ever produces of her self; fermentation being requisite thereto. 2. *Alkalious* spirits, called also *urinous*, by reason of their affinity in many qualities with spirit of urine, are manifestly not simple, but compound bodies, consisting of the volatile salt of the respective concretes dissolv'd in the phlegm, and for the most part accompanied with some little oil; so that these may be refer'd to the article of volatile salts. 3. *Acid* spirits appear to be producible hence, that those drawn from common salt and nitre, are very different in respect of taste, &c. from the bodies they are procured from, which are not properly acid: so that it does not appear, that the spirits pre-existed in that state of those bodies. What further confirms the whole is, that the same body, merely by different ways of ordering it, may be brought to afford either acid, vinous, or urinous spirits†.

Add, that whereas salt is laid down as the principle of all taste; and as bodies are argued to be *saline* for this reason, that they are sapid, 'tis implied in the very notion of a spirit, that it have salt along with it; it being

its taste that characterizes, and distinguishes it from phlegm, and denominates it acid, vinous, or urinous spirit‡.

As to mercury, which is spoke of by chemists as a principle, near a kin to spirit, or rather is confounded therewith; its characters, as deliver'd by writers are, to be a fluid substance, or volatile liquor, which distinguishes it from the saline principles, especially fixed salts; and not inflammable, which distinguishes it from sulphur or oil. But, as this leaves it undistinguish'd from phlegm, others add another quality, *viz.* taste, which is wanting in phlegm, and which brings the chemical mercury precisely to what we call a spirit. The *mercuries* of vegetables and animals, therefore, are already spoken of as *spirits*.

The mercury of fossils or metals is no other than a real running quicksilver, which is a fluid substance, perfectly resembling a metal in fusion, nearly of the same weight with silver, and wetting no substance but gold. This body not being reducible into more simple matters, by any analysis yet invented, is look'd upon as a principle: 'tis commonly held it may be extracted, or obtained from all metals and minerals. And the chemists, in their writings, give us divers processes for the same; tho' the more judicious and sober among them, have long look'd on the pretension as idle and chimerical.

But this principle, *mercury* or quicksilver, M. Homberg gives us sufficient reason to suspect not to be simple; in that it may be destroy'd, which a body perfectly simple cannot. Add, that after its destruction, there remains nothing but a mere earthy matter, without any signs of the other parts before compounded with it. The method that author took to destroy it, was by first changing the running mercury into a perfect metal, gold, by introducing a sufficient quantity of the rays of light into its substance, by a long and expensive operation; and when it was thus rendered a metal, by exposing it to a burning glass, which in a little time carried off the greatest part of the substance in flames, leaving nothing behind but a light earthy dust||. See further under the article *Mercury*.

Salt seems the leading principle of the chemists, who generally grant salts the most considerable and active parts procurable by chemistry from mixt bodies. Its character is to be soluble in water, and unresoluble by fire; but under this character it is incapable of being perceiv'd by us; and needs to be joined or combined with some other principle; to make it sensible.

* Scept. Chym.

† Boyle Scept. Chym.

|| Mem. de l'Acad. R. an. 1709.

‡ Boyle Scept. Chym.

We have three kinds of salts, two whereof are volatile, and the third fix'd; the volatile are *acid* and *urinous* salts; the fix'd *lixivious*, or those drawn from ashes: the two latter are also called *alkaline* salts, or *alkalia*, the one volatile, the other fix'd. We do not know the precise figure of each of these salts; but to judge of them from their effects, the most commodious and probable, according to M. Homberg, the great reformer of the doctrine of salts, is, for *acids* to be pointed, and those points tipped with sulphureous matter; that of urinous seems to be a sponge, containing a part of the acid, and a little fetid oil; that of lixivious salts appears likewise a sponge, containing only the remainder of the acid, which the calcining fire could not carry off.

1. If *acid* salts were found pure, and without any mixture, they would all be of the same nature; and the diversity that appears in them, as procured by distillation, &c. is a full proof of their being compounds, at least of their having something heterogeneous, or adventitious to the saline nature accompanying them. In effect, sulphur, on M. Homberg's principles, is a constant and inseparable attendant thereof: from this appendage of sulphur, it is, that they derive all their activity; and 'tis the same sulphur that characterizes and makes the difference between them. Hence acid salts are ranged by the author into three classes, viz. such as contain an animal vegetable sulphur; under which come all the acids distilled from plants, fruits, woods, &c. and spirit of nitre: such as contain a bituminous sulphur; to which belong the acids of vitriol, common sulphur, and alum: and such as contain a more fixed mineral sulphur; as the acids drawn from sea-salts, and sal-gems.

Those of the first class act more swiftly than those of the other, by reason animal and vegetable substances being very light, i. e. taking a deal of room, and enlarging the surface, give the better handle to the flame to agitate and drive them on; but the same enlargement of the points, prevents their entering into the denser and more compact bodies: those of the second class are the least nimble; by reason the bituminous sulphur is loaden with a deal of earth, which serves it as a matrix; and accordingly, these are incapable, singly, of dissolving metallic bodies. Lastly, the metallic sulphur being the most fixed, i. e. its parts the smallest and most compact, the acids it accompanies, do still retain fine points, and thereby become capable of insinuating into the densest bodies, and separating them: though for the same reason they give but little hold to flame.

Acid salts join'd with *lixivious* ones compose mix'd or intermediate salts, according to the nature of the acids employ'd therein. Thus spirit of nitre, with salt of tartar, produces true salt-petre; spirit of salt, with salt of tartar, produces true common salt; spirit of vitriol, with salt of tartar, produces true vitriol, &c. which are all intermediate salts, i. e. partly fix'd, and partly volatile; the two ingredient salts still retaining their volatile and fix'd natures. *Acids* join'd with *urinous* salts, compose another salt, called *ammoniac* salts, which are always volatile, by reason both the ingredient salts are so. *Acid* salts are usually supposed to be antagonists to *alkalies*, (i. e. urinous and lixivious) by reason, upon their mixture, there always ensues a violent ebullition and effervescence; but it would perhaps be more just to look on this ebullition not as a combat, but rather a suitable and amicable conjunction of two substances, which were naturally united, and had only been separated by the violence of the fire, now restoring themselves into the same places, out of which they had been torn. Accordingly, the latter are compared to sheaths, and the former to points or spicula fit to enter the same. These points or acids do not only enter the pores of sheaths of alkaline salts, but all other bodies, whose pores have a like conformation; whence such bodies are called terrestrial or metallic alkalies*. See more on the subject of acid salts in the article *Menstruums*.

2. In all native salts, both fossil, vegetable, and animal, after the violence of the fire has separated all the volatile parts, there still remains a *fix'd* salt, to be drawn from the *feces* by lotion, or lixiviation; hence called a lixivious salt. These *lixivious* salts are no other than the relics of the *acid*, which the fire was not able to separate from the earth of the mixt; but may be separated by dissolving them in common water. The taste of these lixivious salts is very different, according to the quantity of the acids still remaining after calcination: part of which is capable of being volatiliz'd, and disengag'd by further operations; as, by a more intense heat; or by dissolution, digestion, filtration, and evaporation frequently repeated; or lastly, by adding some urinous salt, to absorb the same.

3. We have three sorts of *urinous* salts: the first, that of plants or animals, which is the same; the second is fossil; and the third of an intermediate kind, partaking both of the fossil and vegetable nature, the first is volatile, and the two latter fix'd. By *urinous*

Y 2 *urinous* salts,

* Mem. de l'Acad. an. 1702.

salts, we mean all such as partake of the taste or smell of urine. Their effect in volatilizing fix'd salts is notorious: for being added to common salt, there arises, by fire, a salt of a volatile kind, called sal-ammoniac. Tho', for volatilizing the fix'd salts of plants, the urinous salts of plants are not so proper as the urinous salts of the intermediate class, such as alum: and for the fix'd salts of fossils, the fossil urinous salt is fittest, viz. borax*.

All the sorts of salts then do throughout appear avowedly compound, and unelementary: and that they are likewise producible, de novo, and convertible into one another, is strenuously argued by Mr. Boyle. The two chief qualities, wherein they all agree, and which therefore make up the common received notion of salt in general, he observes, are to be easily dissoluble in water, and to effect the palate, so as to cause a sense of taste. Now, since the invisible particles, which compose the visible portions of a salt, may be so contrived as to make other parcels of matter, which have the qualities that denominate bodies sulphureous, or spiritous, as we see in nitre's being made inflammable; why may not other corpuscles, or small portions of matters not saline, be so broken into minute parts, and these so sharp and connected, as, when duly associated, to compose a body capable of dissolution in water, and of affecting the organ of taste?

That a disposition to be dissoluble in a liquor, may be acquired by mixture, and a new texture of parts, appears from many instances: and as for the taste, 'tis some question, how far the necessity thereof may consist with another principle; for the purest oils are sapid, yet will not dissolve in water; so that there does not appear any strict connection between being sapid and soluble in that fluid. Helmont assures us, that by Paracelsus's *sal circulatum*, solid bodies among which he instances stones, may be transmuted into actual salt, equal in weight to the body whereof it was made; consequently, as the chemists allow of sulphur, mercury, &c. in such bodies, it appears that the same portions of matter, which pre-existed in the form of those simple ingredients, must, by the operation of fire, and the menstruum, have been converted into salt.

For acid salts; we may instance in salt-petre, which, tho' it have no acid taste, may be made to afford, by distillation, above three quarters of its weight, of a highly acid liquor; yet it does not appear, that such a great proportion of acid particles, or possibly

any proportion at all, is employed by nature, in the composition of nitre.

For urinous salts, we have an instance of their production, in the salt obtained by distillation from foot; for though the wood we burn in our chimneys, seems to have nothing of the taste or smell of urine; nor have the dissolutions of the saline parts of such wood been observ'd to have any affinity in taste or odour thereto; yet when wood is burnt in the fire, and the foot afforded by it distill'd, we get a white volatile urinous salt, like what is afforded by blood, urine, or the like.

For lixivious, or the fix'd salts of calcin'd bodies, the chemists themselves are not entirely agreed. For however the prevailing opinion may be, that these fix'd alkalies pre-exist in mixt bodies; Helmont very ingeniously proposes another origin, and holds them, as to their alkaline form, productions of the fire, by whose violent action, a part of the salt, which in the concrete is all naturally volatile, laying hold of some parts of the sulphur of the same body, both become melted together, and thus fix'd into an alkali: which fixation he exemplifies by what happens when salt-petre and arsenic, tho' both volatile, when expos'd to the fire, are, by its operation flux'd and made to fix each other: tho' what seems to overthrow this account, is, that the fire may not perhaps be always found a necessary agent, in the production of a lixivious alkali: for Mr. Boyle tells us of a piece of true native Egyptian nitre, which appear'd to have all the properties of a fix'd alkali. That author pursues the point further; and shews how to make alkalies from sea-salt and salt-petre, though containing acids; how alkalies may be deprived of their alkaline form, and turn'd into other substances; how common salt may be procured from sandiver, a fix'd alkali, &c. †.

The chemists lay down inflammability as what characterizes their principle sulphur, whence it happens, that three substances, manifestly different in consistence and texture, come necessarily to be refer'd to sulphur: the inflammable substance, obtain'd from mixt bodies, by means of fire, appearing sometimes in form of an oil, which will not mix with water; sometimes in form of an inflammable spirit, which will readily unite with that liquor; and sometimes in form of a consistent body, not unlike fossil sulphur. Now, what in most mix'd bodies is called sulphur need not be conceiv'd as any primordial ingredient, but rather as a generated and resulting thing: for sulphur itself is made of the same universal

* *Hemb. ubi supra.*

† *Producib. of Chem. Princip.*

universal matter with other bodies; and is only a coalition of certain particles thereof, whose aggregate, by having a particular texture, &c. becomes disposed to be turn'd into fire, and usually also into flame; and therefore if the like texture may be found in portions of matter, in other respects different, or if art and chance can frame, and bring together particles of matter so disposed, or can give them such a texture, as disposes them to kindle, flame, or burn away; these qualifications entitle it to the nature of a sulphur, whether it participate of the chemists primæval sulphur, or not.

And that it is not necessary the oil, procured by fire from mixts, be a primæval element, may be argued from the growth of plants, fed merely by water; which nevertheless afford an oil in distillation: and we see that in olive-trees, almond-trees, walnut-trees, &c. the rain water, which insinuates it self into their roots, is, by successive changes of texture, reduced into the oil, which the fruit, by expression, so plentifully yields. And to obviate the suspicion of common water being impregnated with any sulphurous juices of the earth, it may be added that distill'd water will nourish a vegetable. What is more, Mr. Boyle relates an experiment, whereby from two distill'd liquors, both dissoluble in water, and both held by the chemists as elementary bodies, *viz.* oil of vitriol, and alcohol of wine, he procured a considerable quantity of chemical oil, of a very different nature from either of the ingredient liquors*.

This oil, or sulphur, of vegetables and animals, is reducible, by means of lixivious salts, into soap; as that soap is, by repeated distillations from a *caput mortuum* of chalk, into insipid water†.

For the production of that kind of sulphur called *inflammable spirits*, it has already been touch'd on, in speaking of *spirits*. For that of *consistent* sulphurs, it does not appear that any such substance is really procurable, either from vegetables or animals: what the chemists have usually taken for vegetable sulphurs, Mr. Boyle shews to be no other than fossil sulphurs, and to be separated, not from the matter of the vegetable, but from that of the fossil matters used in the process. And as for the sulphurs sometimes obtained from *metals* and *minerals*, 'tis much to be doubted whether they belong'd thereto, as essential ingredients, or were only corpuscles of common sulphur, perhaps, a little alter'd, and mingled with other parts essential to the mi-

neral. Thus we see in native cinnabar, the mercury, which chemists suppose a complete metal, is so mix'd with another body, as not to be distinctly discernible, till separated by the fire: and from this cinnabar, sulphur has been sometimes obtain'd. Add, that as a large quantity of common sulphur is easily separable from vitriol-marcasites; it appears possible for some common sulphur to remain more closely mix'd with the saline and metal-line parts of the vitriol, afforded by the same marcasites; from which latent corpuscles may proceed the sulphurous smell, &c. observ'd in vitriol and its oil.

M. Homberg refines considerably on the notion of the principle sulphur. That oily, or fatty matter, found in the analysis of all plants, and animals, and some minerals, and which has been always taken for the chemical principle sulphur, cannot be a principle, on his foundation; since it may be reduced into other simple matters. Add, that as he lays down the principle sulphur for the only active one, and which of consequence should be found in all mixts; this oily matter is wanting in most minerals, and therefore cannot be the only active principle. In the analysis of an oil, its whole substance resolves into a deal of aqueous liquor, a little insipid earth, and a little salt, partly fix'd and partly volatile; the real principle sulphur, which connected these principles together to make an oil, is lost in the operation; the whole industry of the artist being only able to separate the principles from each other. And as the principle sulphur is only sensible while join'd with some other of the principles, which serve it as a vehicle; it must of necessity escape from whoever would strip it of all heterogeneous matter.

This sulphur may either be considered as *mingled*, and retained in some other matter; which, as it is aqueous, saline, earthy, or mercurial, the result will appear under the figure of spirit of wine, oil, bitumen, or metal; none of which are the principle sulphur: or, it may be considered as *pure*, and without any mixture; in which last sense alone, it is, that sulphur is to be accounted a principle, and the only active principle; leaving to the rest the appellation of sulphureous matters. Now, all mixts, that excellent author observes, in passing a rigorous analysis, lose the principle sulphur, which was the band of the composition; so that the more the chemist endeavours to extricate, and disengage it, the less he finds it.

Earth, by the chemists call'd *terra damnata*, of

* *Producib. of Chym. Prin.*

† See Boyle's *Producib. of Chym. Princ.*

† *Id. Sect. Chym.*

figures; or so minute as that they slip away and cannot be brought to sustain the action of those which otherwise might divide them (*m*).

of all substances seems to have the fairest claim to an elementary nature; in regard the violence of the calcining fire should seem to have driven away all the mercurial and other volatile parts, and have quite burnt out the sulphurs, which are often more fix'd than the rest; as the water, on the other hand, should have dissolved all the fix'd salt: and yet, as to the characters, whereon the simplicity and immutability of the earthy part of bodies are supposed to depend, *v. gr.* its not dissolving in water, its not affecting the taste, and not having flown off with the other parts; it will be found that these too, are producible, may be compounded, &c.

Mr. Boyle has shewn, that not only each of these qualities separately, but all of them together, may and frequently do, arise from the mixing and variously managing of compound substances, wherein they were not before. Thus from oil of vitriol, and spirit of wine, tho' both dissoluble in water, and sapid, he has, by digestion and distillation, procured a large quantity of a substance indissoluble in water, insipid and fixed. So also glass, which tho' not only a compounded, but a recomposed body, (the sand and other stones, which themselves are mix'd bodies, being further compounded with the salts that dissolve them) has yet all the three qualities, which the chemists require in their earth; for 'tis tasteless, dissolves not in water, and is fix'd in the fire. And if ashes be of themselves capable of vitrification, as the chemists teach; how are we sure, that in common ashes, freed after the usual manner, from their fixed salt, what is called a simple earth, may not be a body compounded of two, or more substances, which by their coalition, and new texture, produced by the action of the fire, have been brought to a kind of vitrification?

That earth may be produced *de novo*, may likewise be argued hence, that if salt of tartar be dissolved in fair water, there will remain, after numerous filtrations, and after every single one, a substance in the filtre, which has all the chemical characters of earth. The *terra damnata* of vitriol appears evidently no elementary body, from its purplish colour, its weight far exceeding that of earth, &c.

In effect, in some bodies particularly those of the metalline kind, the calcining fire does not operate as in others, particularly vegetables; since sometimes almost the whole weight of a mineral shall be found in what

7. As they call its *calx*; as we see in tin calcined *per se*: which calx is in great measure reducible sometimes into a body of the same nature with that which afforded it; and sometimes into another body, far from being elementary: as in the reduction of minium into lead, ashes of antimony into glass, &c. See further in the chapter earth, as an instrument.

As vigorously as Mr. Boyle combats the elements, yet he allows, 1. That many mineral bodies may be resolved into a *saline*, a *sulphurous*, and a *mercurial* one; and that almost all vegetable and animal concretes, may be reduced, by fire, into five substances, *salt*, *spirit*, *oil*, *phlegm*, and *earth*; of which the three former being more operative than the two latter, may be look'd upon as the three active principles, and by way of eminence be called the *three* principles of mixt bodies. 2. That these principles, tho' they be not perfectly simple, may, without inconvenience, be stiled the elements of compound bodies, and bear the names of those substances which they most resemble, and which are manifestly predominant in them; because no one of these elements seems divisible by the fire into four or five different substances, like the concrete, whence it was separated. 3. That several qualities of a mix'd body, and especially the medicinal powers, do, for the most part, lodge in one or other of these principles.

It is remarkable enough, that the order wherein these principles succeed each other is different, according as the mixt has undergone a fermentation or not: if it have, the spirituous liquors, and volatile salts rise first, then the aqueous liquors, then fetid oils, leaving a *caput mortuum* at the bottom, which affords a fix'd salt and earth. If it have not fermented, the aqueous liquor precedes the volatile salts, and spirits; the other matters following in the order abovementioned.

(*m*) To this purpose, Sir Isaac Newton closes a fine inquiry into the nature, laws, and constitution of matter—"All these things considered, it seems propable to me, that God, in the beginning, created matter in solid, massive, hard, impenetrable, moveable particles—incomparably harder than any of the porous bodies compounded of them: nay, so hard as never to wear, or break in pieces; no human power being able to divide what God made one, at the creation. While these particles con-

" *tinue*

* *Scept. Chym.*

† *H berg. Mem. de l'Acad. R. an. 1702.*

7. As often therefore as the analysis of a compound has gone so far, as to reduce it into such parts or elements as these; there is an end of all further division, till such time as these simple corpuscles be re-united, either with other simple, or compound ones.

8. Such bodies are by the philosophers called elements; and into such the chemists have often alledged that bodies are by their operations resolved: yet the notion is overturned even by themselves. It must indeed be allowed that fire, air, water, earth, alcohol, mercury, the presiding spirit in each body, and several others, do, when absolutely simple, appear to be fine, permanent elements: but whether such bodies can by any contrivance be procured and exhibited perfectly pure, has not yet been demonstrated: indeed that nothing of this simplicity is found in the common operations of the chemists, has been long ago observed.

9. Fire may perhaps be exhibited pure and elementary, as it penetrates gold, and other of the most solid bodies: but no human art can produce the least drop of pure water, and much less of any of the rest, as air and earth, or the like.

10. Add, that these parts into which bodies are resolved by chemists, are of different natures, easily changeable, and may further be resolved into other parts; as appears from water, spirit, salt, oil, earth produced from animal and vegetable bodies: even alcohol itself, in burning, separates into different parts.

11. Lastly, by re-compounding the chemical elements extracted from any body, we very rarely produce the primitive compound; as may appear from the analysis of wine, blood, and the like. To obtain truth therefore in its purity, and guard against errors, it is necessary to assign certain bounds to the art, beyond which it may not pass. For instance, that from any kind of bodies, animal, vegetable, and fossil, a certain determinate operation in chemistry will always produce certain determinate effects, which are accurately to be distinguished by their several characters: but whether the matters it thus produces actually existed in the body before the operation, will not be always easy to ascertain without other considerations. Thus the spirit of wine obtained from any particular vegetable, by means of a regular fermentation and a proper distillation, is always of the same nature, and produced in the same manner. Nor has it hitherto been possible to obtain this liquor from any other matter: neither is it procurable from this without a double operation. In the mean while, this liquor which the chemist shews us, had no existence before the proper means of fermentation and distillation were apply'd; so that none but a chemist can speak intelligently of its matter, cause and properties. And the same thing certainly obtains in a multitude of other bodies; so that we

restrain

"tinue entire, they may compose bodies of
"one and the same nature and texture in all
"ages: but should they wear away, or break
"in pieces; the nature of things depending
"on them, would be changed; water, and
"earth, composed of old worn particles, and
"fragments of particles, would not be of the

"same nature now, as water and earth com-
"posed of intire particles at the beginning.
"And therefore, that nature may be lasting,
"the changes of corporeal things are to be
"placed only in the various separations, and
"new associations and motions of these per-
"manent particles".

restrain the art within narrow bounds; which art is not depreciated, but rendered the more excellent, useful, and expedient thereby: and thus it is we would be thought to profess chemistry (n).

12. By chemistry then, alone, it is we learn, that in every animal, or vegetable, there is a certain *Aura* or spirit, peculiar to that single body; so subtle as only to be perceivable by its smell or taste, or other effects not found in any other. This *Aura* exhibits the proper character of that body, whereby it is accurately distinguished from all others; it is too fine and thin to be seen by the eyes, though arm'd with a microscope, or felt by the hands, and withal is extremely volatile: so that when pure and single it flies off, by its great mobility mixes with the air, and returns into the common chaos of all volatiles; there still retaining its nature, it floats till it falls down with snow, hail, rain, or dew; by which it again enters the bosom of the earth, impregnates it with its prolific virtue, and at length is received with other juices of the earth into the bodies of animals and vegetables. By such revolution it passes into new bodies, whose mass it animates and directs. This body, from its great penetrability, exquisite subtilty, extraordinary volatility, is called by the ancient chemists, who were deeply skilled in the nature of things, *Spiritus rector*, or presiding spirit. This spirit was lodged by the creator in a tenacious, durable matter, not easily to be dispersed, either by air, water, or fire, and called oil, by whose

(n) Mr. Boyle, in his *Sceptical Chemist*, furnishes abundance of curious things on the chemical principles, or elements. Fire, he clearly proves, does not barely take the elementary ingredients of bodies asunder, but also alters them; and substances are thereby separable from bodies, which were not pre-existent therein: we don't mean materially pre-existent; but only in that form: nor even that some things may not be procured from mix'd bodies that were more than barely materially pre-existent; but only, that several things obtained from a mixed body, exposed to the fire, were not its ingredients before; and that the substances called principles, may be produced, *de novo*, various ways. In order to this, he observes, that the operation of fire does sometimes not only divide mixed bodies into minute parts, but also compounds those parts after a new manner; whence there may result as well saline, and sulphurous substances, as those of other textures. Thus soap, which is known to be an artificial composition of oil or grease, salt and water incorporated together, being exposed to a gradual fire in a retort, will separate, but not into the same substances, whereof it was compounded; but others, of a very different kind. Add, that from many vegetables, there may, without any addition, be procured glass, a body surely not pre-existent in them, but produced by the fire: and from mercury, by a proper management, a fourth part of clear water may be procured; tho' 'tis no way possible any such quantity of water

should be contained in a fluid fourteen times heavier than water: how, then, can we be sure that phlegm is barely separated, not produced in other bodies by the action of fire? for we know of but few, if any bodies, of a more unalterable nature than mercury. To say no more, a vegetable may be nourish'd, and grow up of water alone; and such vegetable, by a common analysis, yield all the principles: now, if out of fair water alone, not only spirit, but salt, oil, and earth may be produced; it follows, that salt and sulphur, &c. are not primogeneal bodies and principles; since they are daily made out of plain water by the texture which the feed, or seminal principle of plants, gives it. Nor would this seem so strange, did not we overlook the obvious, and familiar operations of nature: for if we consider, what slight qualities they are, that serve to denominate a chemical element; we shall find, that nature frequently produces as great alterations in several portions of matter. To be readily dissoluble in water, is enough to make a body pass for a *salt*: yet we see not why, by a new arrangement, and disposition of component particles, it should be harder for nature to compose a body dissoluble in water of a portion of matter that was not so before, than of the liquid substance of an egg, which will easily mix with water, to produce, by the bare warmth of a brooding hen, membranes, tendons, feathers, &c. not dissoluble in water. See the article *Fire*.

whose *Lentor* it is as it were inviscated, and prevented from flying off, and deserting the body, for whose direction it was appointed. Accordingly we find the ancient alchemists maintain that this spirit resides in sulphur.

13. But this oil, whereby the spirit is retained, is much more volatile than the other unctuous ones found in the same body; so that as the body approaches to death, it exhales almost continually with the breath; lest a spirit fit for such great uses should remain useless in a carcass. But so sparing is nature in bestowing this spirit, that she seems only to have instilled the smallest particle of it, tho' this of an excellent kind, and sufficient for the purpose. The ancient adepts have presum'd to measure this minute portion, and tell us that it is always $\frac{1}{1000}$ part of its seminal body. They add, that it is of so active a nature, that when cherished by a brooding warmth, and sustained by a due *Pabulum*, it is extremely moveable, and endued with an incredible power of generating a spirit like it self, as appears from frequent experience: hence they call it the vital spark, *Filius Solis*, the son of the sun, *Spiritus intus alens*, the internal nourishing spirit, and many other the like names.

14. To illustrate this doctrine by an instance, let us take some vegetable body which has certain characters whereby it may evidently be distinguished from all others; suppose cinnamon, which is an aromatic of a most fragrant smell and pleasant taste: distilling a pound of this with boiling water, and taking care that none of it be lost, there will arise a milky, odorous, savoury liquor, to the bottom of which settles a little ruddy fragrant oil, strong of the virtue of cinnamon, and such the first liquor was. After separating the two liquors, let the remaining cinnamon be distill'd with a second water, upon this will arise a limpid watery juice of an acid taste, a faint smell, and affording none of the marks of cinnamon; but so like to many other bodies, as not to be easily distinguished therefrom. The remainder will be of a ruddy brown colour, an austere acid taste, inodorous, and without any thing to denominate it cinnamon: tho' by its figure and external appearance it might still pass for cinnamon; but as to use or excellency has nothing to distinguish it from the bark of any other tree treated in the same manner. All the virtue therefore of cinnamon resides in its distilled water, and particularly in the oil settling at the bottom thereof. If this water be kept a long time in a close vessel, it will deposite its oil, become thinner, and have much less of the aromatic smell; so that this noble property resides chiefly in the oil. If the water impregnated with this spice be separated from its subsiding oil, and placed in a narrow-mouth'd glass vessel unstopped, the whole place will smell of cinnamon, and the remaining water in a short time lose all its aromatic virtue; yet without any greater diminution of weight than would have been found in an equal quantity of common-water under the same circumstances of vessel, place, and time: so that the virtue of the cinnamon water resided in a very small particle thereof. Lastly, exposing the oil in a broad, open glass-vessel to the air, in a wide, open place, the place will be filled with a fragrant odour; but the oil it self lose all its virtue; remaining still much the same in weight, but utterly destitute of its original virtue. It appears therefore, that the whole virtue of the cinnamon resided only in a very small quantity of

oil, and yet made only the smallest part thereof.---And what has been shewn in this instance may be apply'd almost to any other body.

15. Some happy adepts pretend to have seen these spirits sealed up in their several bodies of sulphur, both in metals, and in other fossils; and say that the same, if freed from the restraint, are exceedingly active, apt to insinuate into other kind of bodies, and of great efficacy against diseases.---But as for the truth hereof, I shall leave it to the adepts themselves; declining to enter into any further detail, lest I should be suspected of commending a thing I am not master of (c).

(c) That accurate chemist, M. Homberg, in his new *Essais de Chemie*, lays down the principles of fossil bodies to be salt, sulphur, mercury, water and earth: not that all fossils contain them all; for mercury, he shews, is not a common principle: but some have it, as

metals and metallic minerals; and others not, as stones, earths, fossil salts, &c. The principles of all animal and vegetable bodies, according to the same author, are salt, sulphur, earth and water. *Mem. de l'Acad. an. 1702.*



THE

THE EFFECTS, or PRODUCTIONS OF CHEMISTRY.

1. **T**HE effects of chemistry are reduced to four principal classes or kinds *Extracts*. of things; produced by combination and separation. When a body is resolved into its several parts, and those exhibited separate from each other, this process or manner of action is called extraction, and the parts themselves, especially those of chief use, extracts. Thus, when from wormwood we procure only the bitter, pungent part, separate from the rest, it is called extract of wormwood; and the most active part of iron, when detached from the rest, is called extract of *Mars*. To this class are reducible a multitude of operations employed in the same body; as distillation with and without water, decoction and inspissation produced thereby in various degrees; also tinctures, by whatever menstruum produced, &c.

2. When such an extract is prepared not from one, but several bodies mixed *Clyffus*. together, it changes its name, and is called a *Clyffus*; which term may also be applied to several extracts procured from the same body, and then mixed together: As if, *e. gr.* from wormwood we draw the water, spirit, oil, salt, and tincture, and according to the rules of art unite these again into a mass compounded of them all, and containing the joint virtue of all. To this class are reducible many of the noblest productions of the art, as the more curious *Sapo's*, and an infinite number of others.

3. Magisteries seem to have been thus called by the antient chemists, as *Magisterii*. denoting the capital production, or master-piece of their art. They pretend they are able to take any simple body, and without any change of its weight, or division of its parts, alter it into another exceedingly different from the former, and usually liquid: for instance, to reduce an ounce of gold into a fluid of the same weight, by fire alone, without the addition of any other matter. This, if there be any reality in it, is undoubtedly the greatest excellency of the art; but it is hitherto little known, except that something of the kind seems producible by force of fire. Thus, wax driven out of a retort by the fire, undergoes a surprizing alteration, yet without being separated.

4. Lastly, elixirs seem properly to be where several bodies are mixed to- *Elixirs*. gether, and without altering their weight, changed into quite other forms: so that an elixir is a kind of magistry made of several bodies. This, *Paracelsus* asserts to have done in aloes, saffron, and myrrh; but *Helmont* accuses

him of concealing a solvent capable of working such a miracle ; yet substitutes no better himself : not but something of this kind may be expected from the art. 'Tis certain, a preparation made with tartariz'd tartar, almost did the thing, excepting the exuviae of the saffron : and we make no doubt but that better solvents may be known to others ; it being by no means decent to measure the knowledge of other people by our own scanty pittance ; tho' the chemists are but too apt to sully themselves with boasting.

5. I am not ignorant that the terms abovementioned are sometimes used by good authors in a different sense, but I have some of the best to vouch for the acceptations I have given them : the reader is at liberty to take which he pleases (p).

Of the Use of Chemistry in Natural Philosophy.

Chemistry promotes natural philosophy.

1. CHEMISTRY being employed in the examination of all sensible bodies, 'tis obvious of how much importance it is in the science of natural philosophy, and that it extends itself through all the parts thereof : besides, making great use of fire in the changing of bodies, it becomes on that account of great assistance to natural philosophy, in regard fire is the most general instrument which nature makes use of for the accomplishing of almost all her works. Natural philosophy therefore being the knowledge of all bodies, and of all the modifications which may be observed in them, chemistry has it immediately in view to promote this science ; which I shall endeavour to shew more explicitly. The business of a natural philosopher is to communicate a solid and accurate knowledge of all the bodies in being, and all the affections thereof. Nor can this science be acquired otherwise than by observing, by means of our senses, all the objects which the author of nature has made cognizable thereto : hence, the first and principal part of this science is to collect all the manifest and sensible appearances of things, and reduce them into a body of natural history. Now there are two ways of making such observations ; the first, when we view things nearly as they happen to turn up, without any design or intervention of our own, in which way no great improvements can be expected in the art ; because chance having here the direction, only exhibits occasional, or extemporary properties : the other method is, when after a thorough acquaintance with bodies, we apply them to other bodies equally known, diligently attending to the result, and observing whether any thing new arises. This is by far the more advantageous method to philosophers, as may appear from this consideration, to omit many others, that there are infinite and many of those very powerful properties in bodies, which never show themselves in the ordinary and spontaneous course of nature, but are only

(p) This chapter might be improved from a particular consideration of all the general processes hereafter laid down in the practice ; and much more from all that has hitherto been done by chemists in their laboratories ; so as to include as well the various substances they have made by composition, as the simples they

have obtained by the most perfect analysis, which would furnish out a thousand new productions, never considered or known by those who first invented this superficial division of the effects of chemical operations, into magisteries, extracts, elixirs and clysters.

only brought to notice, when bodies are examined either together; or afunder, by chemical means; and especially by fire, in a manner from which the artift can certainly expect fuch an event to arife therefrom. For the cultivation of this laft method, chemiftry feems the only art that is fit. It refolves a compound into its fimples, and having examined thofe ingredients feparately, unites them again after a certain manner, in hopes of finding fome new appearance, or power turn up. This feparating, or mixing various bodies, and then purfuing them with a determinate degree of fire carefully noted, turns its whole attention to the obferving of what nature will produce in them. This art being thus inftructed in the ways wherein thofe above mentioned obvious phaenomena of nature may be exactly imitated, difcovers and lays before our eyes the very inftruments whereby that powerful agent produces her effects, and thus leads us in her moft fecret ways, and often wifely directs them to our own ufes.

2. Of this we have innumerable inftances; particularly in gun-powder, *Instances of it: Phosphorus*, hot liquors produced by mixture, and the fiery ebullitions of fuch bodies. We own that mechanics, and thofe skilled in hydroftatics and hydraulics, have explained many operations in nature by an infallible method, from the general properties common to all bodies. But from all thefe fciences, how much foever improved, they have never been able to account for thofe effects of bodies which depend on the difpofition peculiar to certain kinds thereof; which the creator has endowed therewith beyond all the reft; as thofe effects would never have exifted, had fuch peculiar power or property of the body been wanting. Thus, if a load-ftone be brought near a load-ftone, iron be brought near the fame, or iron touch'd with a magnetic body be brought near any of the former; what fwift and furprizing effects will arife; effects no where elfe to be found (g)?

3. Now it is evident, that of all the fciences chemiftry is beft adapted for difcovering thefe latent peculiar powers of bodies: whence we may fafely conclude, that the chemical art is the beft and fitteft means of improving natural knowledge (r). They who are poffeffed hereof will be able, by a truly active knowledge, to produce phyfical effects, without refting in fubtilties of words; or idle fpeculations of theory: it being the character of a chemift, that his fpeculations pafs on to effects. Thus, when he explains glafs, he will at the fame

(g) Body being abfolutely paffive, there is a neceffity for fome active power or principle to put it into motion, and make it produce the phaenomena it affords. Body at reft is not only incapable of acting, but even carries an oppofition to action: it has a real power of inactivity, a *vis inertiae*, as we call it; which removes it even out of a ftate of indifferency, and determines it abfolutely to remain inactive: fo that not only a contrary power or principle, but that even in a higher degree than the former, is neceffary to produce action therein.

The active powers which have hitherto fallen under obfervation, are gravity, whereby bodies tend toward the centre; attraction,

whereby the particles of bodies cohere; the caufes of elasticity, electricity, magnetifm, fermentation, &c. See this point further confidered in the notes on the chapter *Of Operations*.

(r) It is by means of chemiftry, that Sir Ifaac Newton has made a great part of his furprizing difcoveries in natural philofophy; and that curious fet of queries, which we find at the end of his optics, are almoft wholly chemical. Indeed, chemiftry, in its extent, is fcarce lefs than the whole of natural philofophy; as might be fatisfactorily fhewn by a thorough chemift; after the manner wherein our learned author proceeds to fhew, that almoft the whole of medicine is chemiftry.

The Theory of CHEMISTRY.

same time shew the manner wherein it may certainly be made; and in accounting for fermentation, he will at the same time produce it; his sayings will be effects; and being free from the enquiry of ultimate causes, he will give the present ones. He does not invoke dæmons, goblins, or spirits, but applies body to body, and thus works his end. He does not regard the names of substantial forms, but sticks to the consideration of the sensible powers peculiarly found in each body; which he exhibits by effects, and shews how they may be applied to the production of the noblest works. He pays no homage to occult qualities, but discovers by his art the effects ignorantly ascribed thereto; and teaches how, when discovered, they may be brought into action. He readily confesses his ignorance as to the creation of seeds, and the peculiar structure given to each body at its first origin; but carefully attends to the appearances arising therefrom, and after noting them faithfully down, applies them directly to the working changes in things. Such are the noble fruits which chemistry, duly cultivated, holds forth no natural philosophers; and from this will arise such a system of physical knowledge as the great Lord Bacon wish'd for, and begun; and which, in pursuance of his design, the immortal Mr. Boyle considerably promoted.

Use of Chemistry in Medicine.

Chemistry necessary to physics, instanced.

1. **T**HE same use which chemistry has in all physics, it evidently has in the medicinal part which treats of the human body, and the action of other bodies thereon: neither of which can be truly understood without the assistance of chemistry. We need not enter into a minute proof hereof. It is by chemistry alone we learn that the first elements of the solid parts of our body are mere earth, bound together by means of an oily *Gluten*, which is inseparable from the same; except by the utmost force of an open fire. The same art also shews us, that water insinuating between the solid parts, does also the office of a binder, hardens and consolidates with them, so as not to be easily separable therefrom. The same also first explained the origin of this earth, oil and water, out of the food chemically considered; as also the origin of the humors in the body from the same food, duly examined by chemical means. And for the parts, kinds, powers, and changes of those humors, who can unfold them without an intimate acquaintance with this art? And as there is a peculiar degree of heat, now determinable by a thermometer, which belongs to a healthy state of body; and as this, when well adjusted, is the proper rule whereby the power of acting is measured; 'tis evident of how much use chemistry is beyond all other arts, for explaining the effects of this fire.

Physiology, how provable.

2. And as those skilled in mechanics and hydrostatics account for a multitude of appearances observed in the affair of health; and as other naturalists daily make other discoveries; so do chemists render many things intelligible, otherwise impossible to be learnt; insomuch that we must of necessity own, that many of the most important parts in all the medical physiology are only to be known by chemistry. The chief article of its praise is, that it alone detects and

and explodes the errors which certain unskillful chemists had introduced into physic; as has been fully shewn by *Boyle, Bohn, Hoffman, and Homburg*, to omit others. Some pretended retainers to chemistry have boasted that they could solve all the points of physiology by their art alone; an error equal to theirs who pretend to explain every thing without any chemistry at all. The business of anatomy is faithfully to relate the structure and parts of the body; of mechanics, to apply their doctrine to the solids; of hydrostatics, to ascertain the common laws of the motion of fluids; of hydraulics, to demonstrate the actions of the same fluids in their passage through known canals: and to all these add what genuine doctrines chemistry will afford the whole, if I mistake not, this will make a perfect medical physiology.

3. Nor does chemistry seem of less service in framing a just pathology. For *Pathology*. how shall we assign the causes, changes and effects of morbid humors in the body, otherwise than from chemical principles? The diseases incident to the fluids, when they stagnate in the vessels, or move too slowly thro' the same; or when they are extravasated, and settle in the cavities of the body, are inexplicable without this art. So likewise the manner whereby a brisk agitation of the oils, salts, spirits, and earth intermixed with our fluids, and circulating therewith thro' the arteries, makes a change in them, is only to be learnt from chemistry. The nature and kinds of acrimony, and how generated in the body, are unintelligible without chemistry. By what means the parts of the blood are coagulated, and how resolved again, is best learnt from our art; which also explains the nature of *Pus, Ichor, Sanies*, fluid *Virus*, the spreading of gangrenes, and the effect of mortifications; concerning any of which we have nothing tolerable without chemistry. Add, that the diseases of the bones, cannot be truly accounted for without the assistance of chemistry.

4. But tho' chemistry be allowed of great use in physiology and pathology; *Semeiotics*. yet that part of physic employed about the signs of health, diseases, and life, was so thoroughly cultivated by the ancient *Grecians*, that many will imagine there is no room for chemistry here. We must own indeed, that the diligence and fidelity of the ancients in collecting the signs of diseases, surpassed all belief; and yet they were wholly employed in observing those indications which nature spontaneously presents to the senses; which point they attended to so solicitously, that they have left little for the moderns to do herein: in so much that the chemist must learn this doctrine wholly from them, before he be qualified to apply his art to the discovery of diseases. And yet the true signification of each sign is not easy to be learnt without chemistry; but satisfactorily with it. This, if we had time, might be shewn in every particular. It was found by them that the too quick pulsations of the arteries denoted a fever present, the degree whereof they estimated by the number of pulsations; and thus that by an increase of the natural heat, the radical moisture was wasted. Consequently that the danger of the disease was different, according to the different degree of heat. *Harvey* further taught, that the too great celerity of the pulsations was owing to the heart, which received the blood from the veins and discharged it into the arteries too quick. Thus far only went the use of the sign which they had observed; but a chemist, upon observing the heat increased by the increase of the number of pulsations, will shew us by
evident

evident experiments, that the most liquid parts will thus be dissipated, the rest thickened, the oils dissolved, mix'd with the blood, ground against the vessels, rendered acrid, made volatile, and become putrid; in that state being protruded into the finer vessels of the brain, will occasion violent commotions therein, nor be easily expelled the blood; that the saline part of the fluids will be so changed as to lose its natural unfitness for motion; whence it now hurries almost spontaneously from place to place, and of mild and saponaceous, which it was before, becomes acrid, biting and fiery, called alkaline. Thus at the same time, a chemist will both collect the true meaning of this sign, and exhibit its general use. The ancients were also used to learn the internal disposition of the body, and the secret nature of diseases, from inspecting the urine. And the modern physicians are forced to do the same; tho' to little purpose. But if a physician skilled in chemistry examine the urine, according to the rules of his art, he will discover a multitude of very useful things by it. Its quantity, colour, taste, contents, sediment, the matter swimming in it, and the froth will shew the nature of the urine, and of the salt, oil, and earth therein contained, and consequently in the blood. Thus he will discover the secret disorders of the humors, and foretel the good or bad events shortly to arise from both; and hence govern the present symptoms, and provide against future ones, that life may not be endangered thereby. In effect, none but a skilful chemist is able to judge accurately of the nature of the spittle, sweat, pus, ichor, or stools, by the signs discoverable therein. Not that a bare skill in his own art will qualify him for this; but if he be at the same time intimately vers'd both in physic and chemistry, by the joint use and assistance of the two, he will be able to discover things, which neither of them singly could have furnished him with. All these particulars, it were to be wished, those, among the physicians, who are chemist-haters, would seriously consider. It would hinder them from rashly condemning an art whose office may be of service, but never hurtful. I own that some chemists, unacquainted with physic, have done much mischief upon their meddling in practice; but this is the fault of the men, not of the science.

Dietetics.

5. Again, no just rules for the diet of healthful persons can be laid down, unless the physician knows what kind of corruption the meat and drink will be changed into, by the particular degree of motion arising from the exercise which the patient uses, or from his peculiar temperature of body. Husbandmen, porters, and the like, who inure their limbs to hard labour, find that fish and flesh, when fresh, and thoroughly salted, quickly putrefy in their bodies by the two vehement attrition thereof: whereas sour brown bread, frumentaceous food and milk, or fish and flesh dried in the air, or smoaked, and well pickled with salt or vinegar, also water or sourish small-beer for drink, are advantageous; in regard the motion of the bile being here too great, tends as well as the whole mass of blood to putrefaction: to prevent which, such foods are to be chosen, as by their sourness, saltness, and hardness, are the most remote from putrefaction. But such as devote themselves to a studious life, and spend their time and spirits in a close application to books; for want of the due motion and exercise, necessary to strengthen their bodies, must use, for their diet, such things as are of easy digestion, and approach as
much

much as may be to the nature of the juices of the human body: for instance, the more tender kinds of flesh, fish, and eggs, fresh, and little salted, which chemistry here shews to be proper. Chemistry, in fine, is the science which of all others best explains what relates to meat and drink, their matter, seasoning, and dressing; to motion, sleep, promoting of excretions, and the passions of the mind, and directs all these to the purposes of health.

6. If we now turn our eyes to the cure of diseases, we shall find, both that the diet suitable for the sick, and most of the remedies necessary, either for supporting or recovering lost health, viz. such as will either correct or expel peccant humors, and make the pungent more mild, must be chiefly furnished from those means and instruments which chemistry best explains, digests in proper order, and fits for the necessary uses. *The rapentics.*

7. Some perhaps may think it absurd if I say that chemistry gives us an exact knowledge of all the ways whereby, from the signs observable in the sick, we know whether, and by what means any thing is to be done to save and recover the patient, and remove, or correct the cause of the disease, and the disease it self. But, for further information on this head, I refer to what I have formerly published concerning the *Methodus Medendi* for the use of young physicians.

8. The truth of what we have asserted may be confirmed by the authority of the great Lord Bacon, who, from abundant experiments, every where recommends chemistry as necessary in all the parts of physic; not to mention Mr. Boyle, who in his elaborate pieces, of the *Sceptical Chemist*, improved with additions and illustrations by himself; of *unexpected failure of experiments*; of *specific remedies*; of *the history of human blood*; *the usefulness of experimental philosophy*; *the mechanical production of qualities*; and in many of his other writings, actually demonstrates the great use of chemistry in every part of physic. If any others need be alleged after these, consult the *English Philosophical Transactions*, and the *Memoirs of the French Academy of Sciences*; where you will see with what industry and emulation the philosophers of the present age have cultivated chemistry, with a view to the improvement of physic: and the *Ephemerides* of the German academists, every where afford us the noblest proofs of the same. 'Tis indeed to be lamented that the physicians best instructed both with learning and experience, are seldom deeply vers'd in chemistry; and again, that the most intelligent chemists have frequently scarce known any thing of physic, to the apparent detriment of both those Arts. Jo. Bobnius and Fred. Hoffman, it must be allowed, are perfectly vers'd in both; and excel the rest. I do not rank Francis de le Boe Sylvius, and Otto Tacbenius, with them, by reason their too great fondness and attachment to chemistry led them to consider it rather as the mistress than the servant of physic. Such matters as chemistry affords, applicable without danger to the uses of physic, I have formerly collected, and inserted in their proper places, in a treatise *de cognoscendis & curandis morbis*, and in another, *de Materia Medica*, published since (s).

Usefulness

(s) The general ignorance of the ancient physicians in the chemical part of their profession, led some of their modern admirers into a persuasion, that chemistry was of no significance therein: as if, because neither Hippocrates, nor Galen, ever saw a distill'd spirit.

A a all

Usefulness of Chemistry in the Mechanical Arts.

Mechanic
arts, what.

1. **T**HOSE arts are vulgarly call'd mechanical, which are performed by the labour of the hands; being very different from that mechanics which lays down the powers of bodies, arising from the common properties of all bodies, which geometricians explain. Chemistry is of no service to this latter; but is of singular advantage to the former, which are employ'd in working upon, and making changes in bodies (i).

Painting.

2. Painting is an art that imitates and expresses sensible bodies by lively colours; and has always been held in the highest esteem (u). There are many arts which contribute their share towards the improvement of painting: but for that part which relates to the colours, their beauty and durableness, chemistry must be allow'd the preference, as may be shewn in few words. The celebrated blue, called *Ultramarine*, which has the advantages of being beautiful to the eye, yet altogether unchangeable, is prepared by a chemical process from *Lapis Lazuli*: and that other common blue, called smalt, is the produce of the same art (x).

all such spirits must be trifles. The first application of chemistry to the purposes of medicine, we have already traced out in the histories of *Basil Valentine*, *Paracelsus*, and *Helmont*.

In the days of *Helmont*, this kind of knowledge had gain'd considerable ground; and two men of eminence, *Sir Theodora Mayer*, and *Quercetan*, professed it publicly at *Paris*; tho' they were strenuously oppos'd therein by the faculty, who commissioned one of their members to write an apology for *Hippocrates* and *Galen*, against the innovators: but these still proving obstinate, were in the year 1603, publicly censured, condemned, and ejected, together with their writings, and their art, by the consent of the whole college. This rash procedure only the more excited the chemists to write and divulge their experiments, and made their doctrine more inquired after: upon which, the physicians of *Europe* divided into sects under the names of *Galenists* and *Chemists*. Many a learned pen was now drawn in defence of the ancients; and many an one to recommend the new-found art. In the mean time, fresh discoveries in chemistry were daily made, and the number of its admirers increased; so that the *Galenists* themselves were at length prevailed upon secretly to try the effects of chemical medicines: which gave them to see, that chemistry was not, as they imagined, to be rashly condemned by the lump. And this at length ended in a friendly union of the two pharmacies, *Galenical* and

3. *Chemical*; which must be allowed a happy coalition. The just compiling of dispensatories, and the art of extemporaneous prescriptions, depend upon a knowledge of chemistry; and to the want of this are owing those errors so frequently committed by dispensatory writers, in ordering the standing medicines of the shops.

(i) "The ancients," says *Sir Is. Newton*, "made two kinds of mechanics: *rational*, "which proceeds by demonstration; and "practical, to which belong the manual arts, "whence the name mechanics was originally "taken. But in regard artificers usually "work inaccurately, by this means mechanics have come to be distinguished from "geometry; so that whatever is accurately "done, is referred to geometry, and the rest, "less accurately performed, to mechanics. "Yet does not the difference lie in the thing, "but wholly in the men. He that works in- "accurately, is an imperfect mechanic; and "he must be allowed the best of all mechanics who works the most accurately of all. "In effect, mechanics, or the mechanic arts, "are, as it were, the basis of geometry; the "drawing of right lines and circles, which "geometry is to consider, being wholly mechanical *.

(u) See *Junius* in his elaborate work *de pictura veterum*.

(x) See *Ant. Neri* Lib. 7. 115; and *Martini*'s notes upon the same.

* *Prof. ad Phil. Nat. Princ. Math.*

3. There is nothing more earnestly desired by the best painters than a beautiful green, which will keep its brightness long in perfection. Now the noble *Ultramarine* blue, not inferior in value to gold it self, being mix'd with a yellow, effectually answers this purpose: so that without chemistry, painting would want two of its best colours. The colours called lacca's, are prepared by a chemical coction and precipitation: and how much of their beauty do pictures owe to the brightness and clearness of these colours? I pass over cinnabar (y), orpiment, ochre, and others; nor shall I mention that a beautiful black colour is made use of by painters, from bones burnt in a close vessel.

4. Chemistry, 'tis certain, is an art very foreign to painting; yet the latter without the former would want its chief ornaments: a chemist may easily do without painting, but a painter scarce at all without chemistry.

5. The chemists have also found a method of painting on gold, and other metals; or of covering it with the brightest and most beautiful colours, composed chiefly of a metalline and glassy matter, with a most penetrating, fix'd, alkaline salt. These Colours, called enamels, *Encausta*, *Amausa*, *Esmailades*, and smalts, by their great vivacity strike the eye with singular pleasure; nor are liable to fade in any length of time. It will here be worth while to turn to the above-mentioned *Neri* (x); but more especially to *Isaac Hollandus*, who gives us many excellent things concerning this noble art; which may vie with all the tessellated pieces of antiquity. 'Tis certain, the fine necklaces and other jewels wore by ladies, by way of ornament, owe much of their lustre to this art (a).

A a 2

6.

(y) *Cinnabar*. See what we have already observed hereof, in the notes.

Vermillion, the ancient minium, is prepared of native cinnabar, by grinding it up with spirit of wine, and urine, and then drying it.

(x) See his whole sixth book.

(a) The enamels or colours used in this art, have for their basis a pure crystal glass or frit, ground up with a fine calx of lead and tin prepared for the purpose; with the addition, usually, of white salt of tartar. These ingredients baked together, are the matter of all enamels; which are made by adding colours of this, or that kind, in powder, to this matter, and melting or incorporating them together in a furnace: when melted, they are cast into water; and when dry, melted over again, and the colour rais'd, or taken down at discretion. For *white enamel*, *Neri* directs only manganese to be added to the matter. For *azure*, zaffer mix'd with calx of brass. For *green*, calx of brass, with scales of iron, or with *crocus martis*. For *black*, zaffer, with manganese, or with *crocus martis*; or manganese with tartar. For *red*, manganese, or calx of copper and red tartar. For *purple*,

manganese with calx of brass. For *yellow*, tartar and manganese*.

Enamelling, to appear in perfection, should only be practised on plates of gold; the other metals being less pure: copper, for instance, scales with the application, and yields fumes; and silver turns the yellows white. Nor must the plate be made flat; for in such case the enamel crackles: to avoid which, they usually forge them either a little round, or oval; and not too thick.

The plate being well and evenly forg'd, they usually begin the operation by laying on a couch of white enamel, on both sides, which prevents the metal from swelling or blistering: and this first lay serves for the ground of all the other colours.

On the plate, thus enamelled with white, they trace the design to be painted; touching and finishing it up with some other colour. This done, the plate is set in a reverberatory furnace, to fix the colour; and the other colours are applied in like manner in their turns. The white colour of the ground serves for the lights, and is therefore spared in all the places where such heightnings are required †.

* *De Arts Vitrar.*

† *Folbican, Princ. de l'Architect. de la Sculpt. &c.*

Staining of
glass.

6. There is also a third kind of painting, which represents things on glass in the most beautiful yet transparent colours: the wonders of this art we see in great perfection in the windows of a church at *Gauda* in *Holland*; which no modern performance can come up to. By means of this art they lay colours on the surface of glass, which being baked by force of fire, their former lustre improved, and their substance diffused to a perfect transparency, penetrates the body of the glass, yet without passing a hair's breadth beyond their assigned limits, or blending with the adjacent ones. I scarce know of any thing more curious and beautiful, or that contributes more to the ornament of churches, halls, and other buildings. The recovery of this art, now almost lost, is hardly to be expected, except from some chemist who should apply the discoveries of his art to this use (b).

(b) The colours used in staining or painting on glass, are all of the metalline, or mineral kind, and not procured without chemical operations, and many of them painful ones too: *black*, according to *Felibien*, is made of scales of iron, ground with glass beads: *white*, with sand, calcined, pounded, mixed with salt-petre, and the mixture recalcined, repulveriz'd, &c. *Yellow* is leaf silver, ground, and mix'd in a crucible, with sulphur or salt-petre; ground a second time and mix'd with oker. *Red* is made of litharge of silver, and scales of iron, gum-arabic, glass-beads, blood-stone, &c. *Green*, of *as usum*, black lead and sand calcined, and incorporated; then salt-petre added; then calcined a second time, and a third time yet ere it be used. *Blue*, *purple* and *violet*, are prepared like green, only leaving out the *as usum*, and in lieu thereof using sulphur, for sky-blue; *perigueux*, for purple; and both for violet. We must add, however, that these colours are not universal; most painters on glass having their particular ones, which they keep secrets.

Method of staining or painting on glass.

To paint on glass, they first design their subject on paper; then make choice of pieces of glass, proper to receive the several parts; and thus proceed to distribute the design on the paper itself into pieces suitable to those of the glass: contriving, that the glasses may join in the outlines of the figures, and the folds of the draperies; that so the carnations, and other finer parts may not be damaged by the lead, in joining the pieces together.

The distribution made, they mark all the glasses, as well as the paper, with letters, or numbers, that they may be known again. Which done, applying each part of the design on the glass intended for it, they copy, or transfer the same upon the glass, with the black colour diluted in gum-water, by tracing and following all the lines and strokes as they

appear thro' the glass, with the point of a pencil.

When the first strokes are well dried, which happens in about two days, if the work be only in black and white, they give it a slight wash over with urine, gum-arabic, and a little black; and this several times repeated, according as the shades are desired to be heightened: with this circumstance, never to apply a new lay till the former is sufficiently dried. This done, the lights and risings are given by rubbing off the colour in those places with a wooden point, or the handle of the pencil.

As to the other colours above mentioned, they are used with gum-water, much as in painting in miniature; taking care to apply them lightly, for fear of effacing the outlines of the design; or even for the greater security, to apply them on the other side: especially the yellow, which is very pernicious to the other colours, by blending therewith.

And here too, as in pieces of black and white, particular regard must be had, not to lay colour upon colour, or lay on lay, till such time as the former are well dried. It may be added, that yellow is the only colour that penetrates the glass, and incorporates therewith by the fire: the rest, and particularly the blue, which is very difficult to use, remaining on the surface, or at least entering very little.

When the painting of all the pieces is finished, they are carried to the furnace to anneal, or bake, and fix the colours thereon. This furnace is small, and built of brick; a little above the bottom is an aperture to put in fuel, over which is a grate, which traverses the furnace, and divides it into two parts; above this is an aperture, thro' which to take out pieces, and examine how the coction goes forward.

On the grate is a square earthen pan, on one side,

7. Somewhat akin to painting is the art of dying, which gives the *Dying*. most beautiful colours to silk, cotton, linen, and woolen; and thus affords us garments, hangings, flags, and the like. This art depends chiefly on three things; viz. 1. Disposing the surface of the stuffs to receive and retain the colours; which is performed by washing them in different lyes, digesting, beating them, &c. in which human urine putrefied, a sharp salt of ashes, divers soaps, and gall of animals, are of principal use; by means whereof the viscid *Gluten* of the silk-worms, naturally adhering to their threads, is washed and cleansed from them; and thus they become fitted to imbibe the colours. By these also the greasy foulness adhering to wool and flax, are scoured off. In every article of which, the use of chemistry is sufficiently conspicuous.—The 2d is, so to grind the colours, as that they may enter the body duly prepared, and preserve their brightness undiminished; in which chemistry is known to be of singular importance, as appears from the manner of dying scarlet, discovered by *Cornelius Drebbel*, citizen of *Alcmaar*; a man of great honour and veracity, perfectly skilled in all the secrets of chemistry, (which recommended him to the king of *England*,) and enumerated among the adepts of those times. Among other of his writings, he left an account of an experiment concerning the method of dying wool with a bright flame-colour; which method his son-in-law, *Kuffibaar*, afterwards putting in practice, raised an immense fortune by it. Spirit of nitre is found to heighten and improve the rich colour of cochineal, into the brightness of burning fire; but then its acrimony corrodes and damages the wool, which is prevented by dulcifying it with tin; after which it neither hurts wool, nor silk, yet retains all its brightness.—The 3d consists in having beautiful colours; wherein the use of chemistry is obvious. I once shew'd some colours, which I had prepared from solutions of copper, to some skilful master-dyers, who were surprized with the beauty of them, and would have given any money to have been able to give colours of such brightness to their stuffs, &c. and no wonder, since the blue, violet, and green of copper, which may be rais'd, or weakened at pleasure, affords so agreeable a variety, that a person

side whereof is a little aperture, thro' which to make the trials, placed directly opposite to that in the furnace destined for the same end.

In this pan are the pieces of glass placed in the following manner: first, the bottom is covered with three strata of plaister, or beaten lime, separated from each other, by two others, of broken glass; serving to secure the painted glass from the too intense heat of the fire. The glasses are laid horizontally on the uppermost layer of this plaister or lime.

This first row of glasses they cover with a lay of the same powder, an inch deep; and over this lay another range of glasses: and thus alternately till the pan is quite full.

The pan thus prepared, they cover up the furnace with tiles, or a square table of earth closely luted all round; only leaving five little

apertures, one at each corner, and another in the middle, to serve as chimneys.

Things thus disposed, there remains nothing but to give fire to the work: the fire for the two first hours must be very moderate, to be increased in proportion as the coction advances, for the space of ten or twelve hours, in which time it is usually compleated. At last, the fire, which at first was only of charcoal, is made of dry wood; so that the flame covers the whole pan, and even issues out at the chimneys.

During the last hours, they make essays from time to time, by taking out pieces thro' the little aperture of the furnace, to see whether the yellow be perfect, and the other colours in good order. When the annealing is thought sufficient, they proceed hastily to extinguish the fire, which otherwise would soon burn the colours, and break the glasses.

son who could die woollen, filken, linen or cotton cloaths therewith, would gain an immense estate.

Art of glass.

8. The art of glass is one of the most useful to mankind: by this, together with the grinder's help, we obviate the natural infirmities of the eyes; without this old man would be debarred the use of letters; to this alone we owe that we are able to sit within doors, or in a coach, or ship, and see all things clearly around; yet without being exposed either to the scorching heat, or freezing cold, or being annoyed with the dust, ingress of extraneous filth, or disturbed by the wind. Pure glass will scarce receive any stain; or, if it do, is quickly cleansed again: it preserves bodies repositied in it without changing them, or being changed by them; and if the glass be perfectly clos'd on all sides, they will remain incorruptible and immutable. Glass is proof against all corrosives; and eludes even the alcahest, if ever there was such a thing; confining it within its body, whilst others are dissolved by it into pure water. It is a principal instrument in chemistry; and were it not for its being common would be priz'd above all metals.

9. It is of ancient origin, being first cultivated in *Egypt*, rendered malleable in the age of *Tiberius*, and in our days is made to the greatest perfection in the island of *Morrana* at *Venice*, and in *Great Britain* (c).

10.

(c) *Neri* traces the antiquity of glass as far back as the time of *Job*: that writer, speaking of the value of wisdom, c. 28. v. 17. says, that gold and glass are not to be equall'd to it: so, at least, our version has it, after the *Septuagint*, *Vulgate*, the *Syriac*, *St. Jerom*, &c. But in other translations, as well as in the original *Hebrew*, the word glass is not seen: instead thereof, the *Chaldees* uses crystal; the *Arabic*, jacinth; the *Italian*, *Spanish*, *French*, *Dutch*, a diamond; the *Targum*, a looking-glass; *Pagninus*, a precious stone; *Vatable*, a beryl, &c. The reason of all this diversity arises hence, that the original word *Zebuchich* comes from the root *Zacar*, which signifies to purify, cleanse, shine, be white, or transparent; whence the same word is applied to frankincense, *Exod.* 30. 34. where the *Septuagint* renders it pellucid: so that the word may equally signify any thing beautiful, and transparent; and is by no means peculiarly appropriated to express what we now call glass*.

Pliny relates, that "glass was first discovered by accident in *Syria*, at the mouth of the river *Belus*, by certain merchants driven thither by the fortune of the sea, and obliged to continue there, and dress their victuals by making a fire on the ground; where there being great store of the herb *kali*, that plant burning to ashes, its salts mixed and

"incorporated with sand or stones fit to vitrify
"or make glass †."

Dr. Merret will have glass as ancient as either pottery, or making bricks; for that a kiln of bricks can scarce be burnt, or a batch of pottery be made, but some of the bricks and the ware, will be at least superficially turn'd to glass: so that it must have been known at the building of *Babel*, and as long before as that art was used; and likewise by the *Egyptians*, among whom the *Israelites* were many years employ'd in making bricks ‡. Of this kind, no doubt, was that fossil glass mentioned by *Ferrant. Imperat.* to be found underground in places where great fires had been||.

'Tis controverted among naturalists to what class of bodies glass ought to be refer'd: *Agricola*, Lib. XII. *de re metall.* makes it a concrete juice: *Vin. Belluacensi*, Lib. XI. calls it a stone; and *Fallopious* reckons it among the *media mineralia* or semi-metals: but *Dr. Merret* observes, that the forementioned are all natural productions; whereas glass is factitious, a compound made by art, a production of the fire, and never found in the earth. To obviate this, *Fallopious* distinguishes between glass contained in its own mine, or its own stone; and true glass that is extracted from the same. Now, the latter, says he, is no more artificial, than a metal is, extracted from its mineral: and as to the former, he urges, that as metal,

by

* *Merret. Observ. in Anth. Neri.*

† *Observ. in Anth. Neri.*

‡ *Hist. Nat. lib. 36.*

|| *Lib. 25. c. 7.*

10. The choice of the materials whereof it is made, the preparation it self, the proper mixture, coction, bringing to perfection, &c. are all owing wholly to chemists.

11. Flint, sand, stones, afford different species of glass; and the calces, according to the different manners wherein they are burnt and extinguished, produce different degrees of beauty in the glass. So the ashes of plants us'd herein, also vary the goodness of glass. A fix'd alkaline salt, sharp and well purified, mixed with a pure calx of flints, yields a glass clearer than amber it self. It must be own'd, that by using a great deal of salt to a small quantity of flints, the glass becomes very clear; but is weak and frail, apt to crack by fire and water, and by age grows dull; and even infects liquors put in it, and sometimes destroys them utterly. So tea remains uncorrupted in green glass, but in the clear kind is totally spoiled. Hence, for our

by having its existence in the ore, so glass by having it in the stone out of which it is educed, is natural. But this argumentation Dr. Merret overturns, by shewing that glass is never found in that form in any mine, but only the sand and stone whereof it is form'd: whereas metals are perfectly form'd by nature into certain species, in proper veins, tho' frequently in such small parcels, that they lie hid, till the fire has collected them together, by separating from them the other matters wherewith they were mix'd. Accordingly, fire only produces metals by its faculty of separating heterogeneous, and congregating homogeneous bodies: whereas it produces glass by uniting and mixing heterogeneous matters, viz. salt and sand into one. Fallopius, indeed, denies this, and pleads, that 'tis false to say that glass is at all made of ashes: the ashes are only added instead of the nitre, used among the ancients, the better to extract the glass out of the substance of the stone: but this is easily refuted: for if the glass were procured from the stone alone, the weight of the metal must be less than that of the stones; whereas in reality it far surpasses it; 100 weight of sand yielding above 150 lib. of glass. Add, that the salts made use of, are of the most fixed kind; which therefore, we cannot suppose to be carried off by the fire; and that in the coarser glasses, which are corroded by the air, one may discern, nay pick out pieces of salt, discovering themselves to be such by their taste.

Dr. Merret gives us a precise and accurate enumeration of the several characters, or properties of glass: the principal whereof are, that it fuses in a vehement fire; when fused, is tenacious, and cleaves to iron; does not consume or waste in the fire, and is the last effect thereof; is ductile and fashionable into any form, while red-hot, but not malleable; friable when cold; diaphanous either hot or

cold; flexible and elastic; disunit'd, and broke by cold and moisture, and especially by saline liquors; is only cut by a diamond or emery; does not let acid juices, or any other thing extract either colour, taste, or any other quality from it; does not wear by the longest use; nor will any liquor make it musty, change its colour, or rust; it softens metals, and renders them fusible; receives all metallic colours, both externally and internally; will not calcine; may be cemented, like stones and metals.

Making of glass.

The materials whereof glass is made, we have already hinted to be salt and sand, or stones. The salt here used, is procured from a sort of ashes brought from the Levant, call'd *polovrine* or *rochetta*; which ashes are those of a sort of water-plant, called *kali*, of the species of that found in some parts of England, call'd *frog-grass*, or *crab-grass*; cut down in summer, dried in the sun and burnt in heaps, either on the ground, or on iron grates; the ashes falling into a pit, grow into a hard mass or stone, fit for use.

To extract the salt, these ashes, or *polovrine*, are powder'd, and sifted; then put into boiling water, and there kept till one third of the water be consumed; the whole being stirred up from time to time, that the ashes may incorporate with the fluid, and all its salts be extracted: then the vessel is filled up with new water, and boiled over again, till one half be consumed; what remains is a sort of lee, strongly impregnated with salt. This lee, boiled over again in fresh coppers, thickens, and in about 24 hours shoots its salt; which is to be laded out, as it shoots, into earthen pans, and thence into wooden vats to drain and dry. This done, it is grossly pounded, and thus put in a sort of oven, called *calcar*, to dry. It may be added, that there are other parts besides *kali* which yield

our art, we chuse a green durable glass made of a great proportion of earth and a less of salt, kept long in fusion, and well elaborated by a strong lasting fire. Consult *Anton. Neri de arte vitraria*; the excellent *Agricola* in his book of metals; *Christopher Merret* in his observations on *Neri*; and *Jo. Kunkel*, who at the expence of that generous prince, the elector of *Brandenbourg*, has brought the art of glass to its highest perfection, in a comment on *Neri*, *Lips.* 1679. 4to. and more especially in a treatise of artificial gems annexed thereto.

12.

yield a salt fit for glass, *i. gr.* alga, or seawrack, the common way-thistle, bramble, hops, wormwood, woad, tobacco, fern, and the whole leguminous tribe, as pease, beans, &c.

The sand, or stones, called by the artists *Tarso*, is the second ingredient in glass; and that which gives it the body and firmness. These stones, *Agricola* observes, must be such as will fuse; and of these, such as are white and transparent, are the best: so that crystals challenge the precedency of all others. At *Venice* they chiefly use a sort of pebble, found in the river *Tesino*, resembling white marble, and called *Cuogolo*; indeed *Anto. Neri* assures us, that all stones which will strike fire with a steel, are fit to vitrify: but *Dr. Merret* shews, that there are some exceptions from this rule. Flints are admirable, and when calcined, powdered, and seared, make a pure white crystalline metal; but the expence of preparing them, makes the masters of our glass-houses sparing of their use. Where proper stones cannot be so conveniently had, sand is used; which is to be white, and small, and well washed before it be applied: such is usually found in the mouths and sides of rivers. Our glass-houses are furnished with a fine sand, for crystal, from *Maidstone*, the same with that used for sand-boxes, and in scouring; and with a coarser, for green glass, from *Woolwich*.

For crystal glass, to 200 *lib.* of *tarso*, pounded fine, they put 130 of salt of *polverine*, mix them together, and put them into the *calcar*, a sort of oven or reverberatory furnace, which is first well heated. Here they remain, baking, frying, and calcining for five hours; during which the workman keeps mixing them with a rake, to make them incorporate: when taken out, the mixture is called *frit* or *bolino*.

Note, there are three kinds of *frit*: that here described is crystal frit: the second, or ordinary frit, for the common white, or crystalline metal, is made of the bare ashes of *polverine*, without extracting the salt from them. The third, for green glass, is made of

common ashes, without any preparation, and a hard sand above mentioned.

It may be further observed, that glass might be made by immediately melting the materials, without thus calcining, and making them into frit; but the operation would be much more tedious.

Now, to proceed to the operation of making the glass itself; they take of this frit, and set it in melting-pots in the working furnace; adding, in each pot, a proper quantity of a blackish stone, not unlike load-stone, and called *manganese*, which serves to purge off that greenish cast natural to all glass, and to make it clearer, and more azure. While the whole is in fusion, the workman, here called the *conciator*, in the green glass houses the *fonder*, mixes the metal well together, with his *square*; and with a ladle skims off the sand, over which is a whitish salt, call'd sandiver, continually cast up from the metal, and swimming on its surface; which is always in the greater quantity, as the *polverine* was weaker; and which, unless well purg'd off, would make the glass brittle, and unfit for working.

When the vitrefaction is completed, and the metal found sufficiently clear, and fine; they proceed to form it into the works required: in order to this, the operator dips a hollow iron into the melting pot, turns it about, and takes out enough for the vessel or work it is intended for; the metal sticking to the iron, like some glutinous or viscid juice. While 'tis yet red-hot, he rolls it to and fro on a marble, to unite its parts more firmly: then gently blowing into the iron, he raises or swells the metal, just as in blowing into a bladder. This blowing he repeats again and again, till he has attained the destin'd bulk; then whirling it about his head, he lengthens, and cools the glass; and, if the design require it, moulds it in the stamp irons, and flats the bottom, by pressing it on the marble: and thus delivers it to the master workman, who breaking off the collet, by which it adhered to the blowing-iron, proceeds, as occasion requires, to fashion it further; *i. gr.* if it be for a drinking glass with his *ponteglo* he sticks the glass, and scalds it;

12. There is another species of glass contriv'd by chemistry, which, tho' transparent, is at the same time adorned with a beautiful colour, so as almost to equal the brightest native gems. It is made of the purest and most perfect glass, intimately penetrated, and embodied with metals; which thus communicate to it a durable lustre: in effect, there is scarce any gem, or stone, valuable for its colour, but may be imitated in glass prepared after this manner (d). If the art of glass-making should once arrive at such a perfection, as

that it; with his *passage* makes the bowl; with his *procello* widens and makes it hollower; then with his *sheers* cuts off what is superfluous. Thus with *blowing*, *pressing*, *scalding*, (which are to be repeated as oft as the glass cools.) *amplifying*, *cutting*, &c. the work is brought to the form intended; and, if need be, feet and handles are fastened on; and rigarines and marblings wrought.

As fast as the master finishes them, another takes them up with an iron fork, and places them in a *tower*, over the melting-furnace, to *anneal*: into this tower, there is a hole, by which the heat and flame are received from the furnace; and after the glasses have stood here some time, they are put into iron pans call'd *fraches*, which by degrees are drawn, by the *sarale-man*, further off, along an appendage of the tower called the *leer*, five or six yards along, that they may cool by degrees: when they are arrived at the end of the leer, they are quite cold, and thus taken out, fit for use*.

(d) Tho' crystal, in not being fusible, becomes unserviceable of dyes, or tinctures in substance; yet the industry of the chemists has found means of making it serve for the basis of precious stones, with all the advantages of colour. Tho' we cannot fuse it; we can calcine, and make frit of it.

The art of imitating precious stones in glass, is too curious and considerable to be passed over without further notice; some of the leading compositions therein, we shall briefly point out, on the authority of the never enough to be commended *Neri*.

To make a sea-green glass; take crystal frit, without allowing it any manganese; melt it, and when clear, a salt will be found swimming a-top, in form of an oil, which is to be skimm'd off, as long as any rises. When the glass is perfectly clarified, mix calcined brass, and zaffer; and add the mixture to the melted crystal. Let the whole stand three hours, that the colour may incorporate with the metal: then stir and mix them again; take a proof, and either heighten or take down the colour.—For an emerald-colour'd glass, use crystalline metal that has had no manganese, pass

B b

it thro' water once or twice, to get out all the salt; add half the quantity of common white metal made of pulverine; and when the mixture is well purified, add brass thrice calcined, and *crocus martis* calcined with brimstone, and reverberated: if any blueness remain, add more of the *crocus*.—For a turquois-colour'd glass, evaporate all the moisture from sea-salt, till it become white; then pulverize it: this powder add, by degrees, to a sea green crystal metal, mentioned above, mixing it well together, till the sea-green lose its transparency, and become opaque; which is the effect of the salt, now vitrified. Upon this, a little paleness arises, and by degrees the sky-blue, which is the colour of a turquois stone.—To make calidonys, jaspers, and agais, in glass; dissolve silver in *Aqua fortis*, and also mercury in *Aqua fortis*; mix the solutions in a glass body, and to the mixture add sal-ammoniac; when dissolved, add zaffer, manganese, ferretto, *crocus martis*, thrice calcined copper, blue smalt, and red lead, all in powder; keep the body stopp'd ten days, stirring it daily: then set it in a sand furnace; in twenty-four hours the *Aqua fortis* will be evaporated, leaving a powder at bottom: Lastly, take very clear metal, made of broken pieces of crystal, and crystalline vessels, and white glass that has been used: to twenty pound of this add two ounces and a half of the powder; mix, and incorporate them, and let them stand in the fire twenty-four hours; upon this, when grown cold, waves and clouds of beautiful colours will begin to appear. Add tartar, vitrified soot, and *crocus martis*, calcined with brimstone, all powdered and mix'd, to the composition: let it boil, and settle twenty four hours; and then make a glass body of it, which put in the furnace again and again till there appear fine streaks, and shades of blue, red, sea-green, yellow, and all other colours; in which state it is ready to be wrought into variegated vessels, &c.

To make a gold-yellow in glass, mix crystal frit with common glass frit and to the mixture add tartar beaten and searced, and manganese; place them in a furnace four days, with an ordinary fire; when sufficiently purified, and coloured,

* Antonio Neri de Arte Vitraria, and Dr. Merret's notes on the same.

that by means of fire, we might be able to make glass once and a half heavier than at present; we should then, with the assistance of metals, make artificial gems equally bright and beautiful as the natural ones: since by how much the transparent matter is more dense and solid, the more lively and glittering will the metal appear thro' it. But as art has not yet discovered any such method of giving density to glass; the matter of factitious gems is too porous and rare; and thus produces a weaker and more languishing reflection of the rays; which renders them inferior to the native kind. Some have endeavoured to increase the weight of glass by adding lead to it; but this at the same time increases its softness. There is therefore still ground for those who pursue chemical enquiries, to endeavour at a method of condensing the substance of glass; which will amply reward them for their pains (e).

13. Another thing required to the perfection of the art of making artificial gems is, that they may be able to render their glass so hard and rigid, as that it may lose nothing of its polish and lustre, by the frequent attrition it will be subject to in wearing; but like the natural precious stones remain incorruptible and unchanged.

14. Lastly, having rendered their matter thus ponderous and hard, they must impregnate it by the fire with a rich tincture of metals, and thus shape, or figure it into pieces of many sides; by which means they may be able to excel nature, both in the magnitude and variety of their gems; since they have a great stock of colours which may be diversified almost to infinity; where-with they may tinge their glass, by mixing them with it when in fusion; or

by
loured, work it.—*For a granat colour*; to crystal, and common frit mix'd, add manganese, and zaffer; put them in a pot, and keep them in the furnace twenty four hours.—*For an amethyst colour*; to crystal frit add manganese and zaffer, as before.—*For a saphyr colour*; either to common or crystal frit, add zaffer and manganese; mix and melt them in the furnace, and when well colour'd, work it.—*For a black colour*; to crystal and common frit, add calx of lead and tin; mix, and set them in the furnace: when the metal is melted, and pure, add powder of calcined steel, and scales of iron; after boiling with the mixture, let them stand and settle twelve hours.—*For a snow white*; to crystal frit add calcined tin and manganese; mix them, and set them in the furnace to refine, for eighteen hours: then cast the matter into water, and make a proof: if it be too clear, add more of the tin.—*For a marble colour*; crystal frit melted, and work'd without purifying, suffices.—*For a deep red*; put crystal frit, broken white glass, and calcined tin, in a pot to melt and purify; and when in fusion, add calcined steel, and scales of iron, well powdered, thereto; mix, and let them incorporate five or six hours. Make an essay, and if the metal be too black or opaque, add brass calcined to a redness; mix, refine, and

make an essay as before, till it be of a blood-red; and work it speedily, lest it lose its colour.

(e) It is no inconsiderable improvement of the art of imitating gems in glass, to make use of glass of lead; the stones produced hereby, far exceeding those made of common glass, or even of crystal, in point of colour. To prepare this glass, the lead is first fused and calcined in a kiln; then re-calcined by a reverberatory fire; and lastly, pulverine or rochetta frit being mixed therewith, and the whole set in the furnace for ten hours, it is cast out into water, and the glass separated from the lead.

This glass may be blown or work'd into vessels, after the usual manner.—It becomes of an emerald colour, by the addition of pulverine frit to bury it, and brass thrice calcined, and *crocus Martii* made with vinegar, incorporated therewith.—A *topaz colour*, by using crystal frit instead of pulverine frit, and adding half the quantity of yellow glass.—A *granate colour*, by adding crystal frit, manganese, and zaffer.—A *gold colour*, by adding crystal frit, brass thrice calcined, and *crocus Martii*.—*Colour of lapis lazuli*, by adding the snow-white glass above-mentioned, with the painters blue small*.

* *Neri ubi supra.*

by smearing them on the surface of the glass, and making them penetrate by fire, if the ancient art should ever be restored.

15. These three sure and solid foundations for making artificial gems are furnished by chemistry alone; which will likewise afford daily occasions of making further improvement in this noble manufacture. But as the artists have hitherto in vain attempted to give this density and hardness to the matter of glass; others have prudently bethought themselves to take pure and perfect rock-crystal, and try whether to the weight and hardness which it has from nature, so as to enable it to cut glass; they could not make it susceptible of metalline colours, yet without detriment to its transparency, and the brightness of its polish. This might be effected with some success by heating the crystals red-hot, and then extinguishing them in colour'd fluids; but that this method disposes them to crack and flaw (f). Others have attempted the like by cementing crystals with various metals, which being dissolved and carry'd upwards by the fire, penetrate the substance of the crystal. Lastly, it may not be impossible to find some matter richly impregnated with a metalline colour, which being laid thin over the crystal, may by force of fire be driven into the body of it, and give it a beautiful dye. In fine, from the whole, it seems to follow, that if there be any good to be hoped for in this elegant art, it is from chemistry we must expect it. Nor do I see how any other art can contribute any thing hereto (g).

16.

(f) See *Boyle of Gems*, pag. 19, 44.

(g) M. Homberg gives us a new and curious application of the art of glass to the copying of *engraved stones*, and taking figures or impressions thereof, equally beautiful with the originals. He even assures us, that he made copies this way from a great number of such stones, furnished him by the Dutchess of Orleans, in such perfection, that some of the most experienced persons took them for antique.

"The whole method consists in moulding the graven stone in a fine earth, and imprinting therein a piece of glass half melted by the fire, in such manner, as that the figure of the stone remains accurately impressed on the glass."

The chief difficulty lies in finding an earth fine enough to take the figure, and yet that shall not melt, mix, stick to, and incorporate with the melted glass, which itself is little else but a sort of earth. The character of such earth must be, that it have as little salt as possible; salt disposing it more easily to fusion. Of all the earths whereof M. Homberg made trial, the least saline, and that which he found fittest for the purpose, was a sort of chalk, called *tripoli of Venice*, commonly used in polishing looking-glasses, optic-glasses, and precious stones. Tho' there is also a coarser

tripoli found in France, of some stead in saving the too great expence of the former.

The process is thus; pounding the French *tripoli*, pass it through a hair-sieve: scrape the *tripoli of Venice* very fine with a knife or piece of glass; pass it thro' a fine silk-sieve, and grind it in a glass mortar, with a pistle of glass.

Proceed now to moisten the French *tripoli* with water, till it may be made into a paste by squeezing it between the fingers; and therewith fill a little flat crucible, pressing it lightly into the same: then strew some dry powder of the Venice *tripoli* over it; and on this lay the stone intended to be moulded; pressing it strongly into the same with the fingers, and flattening down the *tripoli* all around it. Here letting it remain a while, for the moisture of the French *tripoli* to penetrate the Venetian; turn the crucible upside down; upon which the stone falls out, leaving its impression behind.

The crucible having now stood till perfectly dry, take a piece of glass of any colour at pleasure, and of a size answerable to the work intended, and expose it in a furnace till it begin to shine, which shews it sufficiently softened for the impression. Upon this, immediately apply it with a piece of iron into the cavity of the mold; and as soon as it has taken

Metallurgy.

16. The art of metals has so near a dependance on chemistry, that it seems to claim it as its own. I do not here mean the art which pretends to be employ'd in the making, and transmuting metals; concerning which, I shall give my real thoughts, when I come to speak of the use of chemistry in alchemy; but I mean the art which teaches how to prepare and fit metals for human uses, or even ornaments. Gold is frequently too pale on many accounts, wanting its fine yellow colour, which must be raised by a chemical cement, or by *Regulus* of antimony, as is now practised in *Holland*; where the gold pieces are brighter than elsewhere, owing to the peculiar skill of the mint-master.

17. The same metal, if it be pure, is too soft for the uses of coinage; and must be brought to a due temperature, by a mixture chiefly of copper and silver. The like may be said of silver, which is too soft and ductile for common use, and needs a proper addition of copper, to fit it both for coinage and family service.—We need not mention that by a mixture of copper and calamine, a metal is made vying with gold in brightness; nor prince's metal, or the metal denominated from prince *Rubert*; which is made of brass and zinc; and which being gilt, equals in brightness the fairest gold. So the valuable and beautiful art of gilding and silvering the baser metals, is the work of chemistry. From which few instances it will be easy to infer, what a multitude of other effects might be produced, if a skilful chemist were to employ his art in the mixing of metals.

18. Nor does medicine reject the use of cups which give a medicinal virtue to the wine pour'd into them; as has long ago been found in the *Regulus* of antimony tempered with other metals. 'Tis pity *Hellmont* should have deprived the diseased of the benefit they might have received from a metalline matter he talks of; a ring of which wore for the space of a few minutes, removed all pain of the hæmorrhoids, either internal or external; at the same time calming hysteric fits and spasmodic disorders (*b*). It may be worth while to make experiments with this view; there being frequently a hidden virtue in such compounds, and no great danger in making trials.

19. Again, metallurgy, which is employed in judging and distinguishing the fossil ores found in mineral veins, and preparing them into proper and pure metals, depends altogether on the art of chemistry; which may appear from hence, that chemistry chiefly owes its rise to these occasions, and has in later times produced many improvements in the art of metals. They who have carefully read *George Agricola*, *Lazarus Erker*, *J. Rudolph Glauber*, and others who chiefly copied after them, will need no proof hereof; for such as have not, I shall subjoin a few instances.

20.

taken the impression, set the crucible in a warm place in a furnace, that the glass may cool by degrees, without craking: when cold, it is taken out of the crucible, compleat.

To copy a stone *in creux*, that is imboss'd or wrought *in rilievo*; or to copy *in rilievo* a stone wrought *in creux*, proceed thus: Take the impression of the stone in sealling-

wax, or sulphur, and pare off all that is superfluous on the edges; mould this waxen impression in a crucible of *tripoli*, in the same manner as if it were a stone; and take an impression thereof in a piece of glass, as above-taught*.

(*b*) See his Works, p. 745. §. 39.

* *Mem. de l'Acad. an. 1716.*

20. Those conversant in chemistry know, that a matter is easily prepared, which being mixed with gold, silver, or other metals, immediately renders them all volatile, so that with a gentle fire they may be driven over in glass vessels, or drawn by the retort. Nor is it less certain that among the ores of metals, certain bodies are often found which exhale and dissipate the mineral matter, when exposed to the fire, in order for fusion, to the great loss of the miners. In effect, a pernicious consuming sulphur is frequently found adhering to gold, which has wasted many thousand pounds of that metal, even while only exposed to torrefy by the fire. But the chemists have found a method of fixing, in a moment, all these volatile ores, and making them endure the most violent fire, so as that they may be fused, and hereby separated from the rest. 'Tis known, also, that *Regulus* of antimony, mixed with double the quantity of corrosive sublimate, will become by a moderate degree of fire, an unctuous substance, extremely volatile; and the same, by a gentle warmth, will emit poisonous fumes; and by the repeated action of the fire, turn into a limpid oil, which smokes spontaneously. What is still more surprizing, a pound of this oil being poured on the like quantity of fair water, the effect is, that it immediately turns white, and precipitates a white metallic *calx* of antimony, which will sustain such a degree of fire, as that it may be melted into a mass like silver, being the best *Regulus* of antimony that can be made.

21. By this experiment we are instructed, to pour water on the volatile ores, and observe whether by this means, they do not yield more metal than otherwise. The addition of iron likewise at the time of calcination, will frequently absorb the sulphur, so as to prevent its carrying off the metalline matter. Fix'd alkaline salts have likewise been found beneficial for subduing and resolving sulphurs, or acids, which being mix'd with the metalline matter, made it exhale by the fire. The rich silver mines of *Peru* are infested with a malignant unctuous matter, which occasions the metalline substance, on the application of fire, to fly off; by which means the greatest part of the silver was formerly lost; but since, the chemists have taught them to torrefy the ore, by exposing it to a gentle heat slowly applied, and then breaking it to pieces, to grind it with quicksilver, wash it in a proper manner with water, and lastly, reduce the pieces into a mass, by expelling the mercury which had drawn and united this to itself, scarce a grain is any longer lost; and thus are immense treasures saved. How have the miners and assayers lamented the difficulty of extracting the pure silver from tin mix'd with it; but since chemistry has shewn the way of evaporating the tin, by the admixture of melted copper, the silver is now easily procured, and without much charge; being found pure in the copal. I could add infinite other instances of the benefits accruing to metallurgy from chemistry; but the present occasion neither requires nor admits of them.

22. It were indeed to be wish'd that our art had been less ingenious, in contriving means destructive to mankind; we mean those instruments of war, which were unknown to the ancients, and have made such havoc among the moderns. But as men have always been bent on seeking each other's destruction.

tion by continual wars; and as force, when brought against us, can only be repelled by force; the chief support of war, must, after money, be now sought in chemistry.

23. *Roger Bacon*, as early as the twelfth century, had found out gun-powder, wherewith he imitated thunder and lightning; but that age was so happy as not to apply so extraordinary a discovery to the destruction of mankind. But two ages afterwards, *Barthol. Schwartz* (i), a German monk and chemist, happening by some accident to discover a prodigious power of expanding in some of this powder which had been made for medicinal uses, he apply'd it first in an iron barrel, and soon after to the military art, and taught it the *Venetians*. The effect is, that the art of war has since that time turned entirely

(i) What evidently shews the ordinary account of its invention false, is, that *Schwartz* is held to have first taught it the *Venetians* in the year 1380; and that they first used it in the war against the *Genoese*, in a place anciently called *Fossa Caudeana*, now *Chioggia*. For we find mention of fire arms much earlier: *Peter Messius*, in his *variae lectiones*, relates, that *Alphonfus XI.* king of *Castile* used mortars against the *Moors*, in a siege in 1348; and *Don Pedro*, bishop of *Leon*, in his chronicle, mentions the same to have been used above four hundred years ago, by the people of *Tunis*, in a sea fight against the *Moorish* king of *Sevil*. *Du Gange* adds, that there is mention made of this powder in the registers of the chambers of accounts in *France*, as early as the year 1338.

The composition of gun-powder is as follows: Take six pound of salt-petre well purified, and reduced to powder: one of sulphur, likewise purified and powder'd; and at least one of charcoal: put these ingredients in a mortar, moisten them with water, spirit of wine, vinegar, or urine, and pound them for twenty-four hours, remembering to moisten from time to time, to prevent the mass from thaking fire. This done, squeeze it thro' a sieve. By this means it will be formed into little grains or globules, which being dried are the gun-powder*.

Other authors prescribe other proportions: *Semenowitz*, for mortars directs 100 pounds of salt-petre, 25 of sulphur, and as many of charcoal; for great guns, 100 pounds of salt-petre, 15 of sulphur, and 18 of charcoal; for muskets and pistols, 100 pound of salt-petre, 8 of sulphur, and 10 of charcoal†.

Miethius extols the proportion of one pound of salt-petre to three ounces of charcoal, and two, or two and a quarter of sulphur; than which, he affirms, no gun-powder can possibly be stronger. He adds, that the usual

practice of making the gun-powder weaker for mortars than guns, is without any foundation, and renders the expence needlessly much greater; for, whereas to load a large mortar, 24 pound of common powder is required; and, consequently, to load it ten times, 240 pound: he shews, by calculation, that the same effect would be had by 180 pound of the strong powder‡.

The explosion of gun-powder is thus accounted for by *Sir Isaac Newton*: "The charcoal and sulphur easily taking fire, kindle the nitre, and the spirit of the nitre being thereby rarified into vapour, rushes out with vehemence, much after the same manner as the vapour of water out of an æolipile; the sulphur also being volatile is converted into vapour, and augments the explosion; and the acid vapour of the sulphur, viz. that which distils under a bell, into oil of sulphur, entering violently into the fix'd body of the nitre, lets loose the spirit of the nitre, and excites a greater fermentation, whereby the heat is further augmented, and the fix'd body of the nitre also rarified into fume, and the explosion thereby made more vehement and quick§.

"If salt of tartar be mixed with gun-powder, and that mixture be warm'd till it takes fire: the explosion will be more vehement and quick than of gun-powder alone: which can proceed from no other cause but the action of the vapour of the gun-powder upon the salt of tartar, whereby that salt is rarified**."

This makes what they call *pulvis fulminans*, whose effect *Sir Is. Newton*, in the same work, accounts for from the great attractive force, whereby the acid spirits of the sulphur and nitre rushing towards one another, and towards the salt of tartar, by the violence of the shock turn the whole into vapour and flame††.

* *Wolffii Element. Pyrotech.*

† *Pyrotech.*

‡ *Artiller. Prax. Recent.*

§ *Opticks*, p. 317.

** *Newt. Opt.* p. 317.

†† *Ibid.* p. 352, 353.

entirely on this one chemical invention; so that the feeble boy may now kill the stoutest hero: Nor is there any thing, how vast and solid soever, can withstand it. By a thorough acquaintance with the power of this powder, that intelligent *Dutch* General *Coborn* quite alter'd the whole art of fighting; making such a change in the manner of fortification, that places formerly held impregnable, now want defenders. In effect, the power of gun-powder is still more and more to be fear'd. I tremble to mention the stupendous force of another powder, prepar'd of sulphur, nitre, and burnt lees of wine; to say nothing of the well-known power of *aurum fulminans*. Some person taking a quantity of fragrant oil, chemically procured from spices, and mixing it with a liquor procured from salt-petre, discover'd a thing far more powerful than gun-powder itself; and which spontaneously kindles and burns with great fierceness, without any application of fire (*k*). I shall but just mention a fatal event which lately happen'd in *Germany*, from an experiment made with balsam of sulphur terebinthinated, and confined in a close chemical vessel, and thus exploded by fire; God grant that mortal men may not be so ingenious at their own cost, as to pervert a profitable science any longer to such horrible uses. For this reason I forbear to mention several other matters far more horrible and destructive, than any of those above rehearsed.

24. Those anciently called in *Asia* *Magi*, were the wiser men of those times, *Natural* as is allow'd among the learned; nor was the word always used in its proper *magic*. sense to denote a sort of ill-disposed operators, dealers in deceit, and servants of the devil; as may appear from the *Magi*, or wise men, of *St. Matthew* (*l*), who were persons skillful in astronomy, and worshippers of the true God; to whom they were also acceptable. It may be added, they were in great esteem with princes, and always admitted into their most secret councils. *Zoroaster* himself, the founder of this sect, was a king of *Bactria*, famous for his great knowledge of the stars; into the motions whereof, and the principles and origin of things, he is said by *Justin* (*m*) to have made a strict search. Accordingly, *Cicero* informs us (*n*), that the kings of *Persia* were always instructed in the magic arts, before they were admitted to govern the state. He adds (*o*), that the *Magi* in *Persia* were wise and learned men. From hence it arose, that an ignorant set of people, covetous of dishonest gain and fame, have endeavour'd to cover their sleights and impostures under the specious name of magic; by which means, their frauds having been frequently detected, a scandal has redounded to the name, and magic thus

(*k*) On this occasion we cannot omit to admire an instance of a noble and generous principle, in the late king of *France*, *Louis XIV.* A *Roman* chemist, *S. Poli*, having discovered something of this kind, of prodigious effect, came to *France* in 1702, on purpose to make an offer of it to that prince; who, tho' he was then going to be engaged in a war against a powerful confederacy; yet voluntarily renounced all the advantages of such a secret; handsomely rewarded the inventor, but enjoin'd him to let it perish*.

A drachm of compound spirit of nitre being poured on half a drachm of oil of caraway seeds *in vacuo*; the mixture immediately made a flash like gun-powder, and burst the exhausted receiver, which was a glass six inches wide, and eight inches deep †.

(*l*) *Matth.* ii.

(*m*) *Justin.* I. i.

(*n*) *De Divinat.* I. 91.

(*o*) *Id.* I. 47.

* *Hist. de l'Acad. R. des Scienc. an. 1714.*

† *Newt. Opt.*

thus become exploded, after the same manner as mathematics have unjustly been. The true *Magi*, by a close pursuit of nature, discovered things which the creator had designedly laid deep, as a reward for labour and industry; whence they appear'd, to the vulgar, as endued with a kind of supernatural knowledge, and were accordingly supposed to hold intelligence with dæmons, and to receive their chief notices from them. Hence they were venerated rather out of fear than love; especially as an opinion had prevailed in all ages of the world, that there are both good dæmons and bad, who, being intimately skilled in natural things, were induced either out of love, or hatred to mankind, to make use of their knowledge to gain men to them, either to save or ruin them. Whether the opinion were true or false, I shall not here enquire. The powers, instruments, and other virtues and riches of nature, as settled by the creator, are many of them unknown; but by those we do know, we may be inclin'd to believe, that there shall infinite things be clearly reveal'd to mankind, of which there is not now the least appearance. Who knows but there may be beings able to see further into things than the wisest of man have hitherto done? Who knows but such spirits may have a perception of bodies, understand their powers, see the order of causes, view present things, foresee future things, and know past ones, even without the assistance of bodily organs? It is no absurdity to suppose, that such spirits might infuse their thoughts into the minds of men; since, in reality, we are as much unacquainted with the connection and mutual intercourse between thinking beings, as with the numbers and different species of beings endowed with understanding, will, and passions. Nor do we so much as know the true reason, why a moving body communicates motion to another, which it happens to strike against. Who will venture to deny the existence of a light incorporeal kind of beings fleeting among us, when we see spectres emerge out of a concave mirror, and subsist in the liquid air so clearly, as that tho' acquainted with the thing, we are half terrified at the sight, to find an empty impalpable image, exhibit such dimensions, magnitude, and vivid colours, with whatever else is discoverable in a solid body? And as our bodies have a mind united with them, by means whereof they see external things, why may not this fleeting species be also united with souls, and thus enabled to move, penetrate, and change things? Whether the case be thus, or not, I do not affirm; perhaps hereafter we may be allowed to know. In the mean while I neither assert, nor deny, that men by the assistance of dæmons may have known, or done things, beyond what could have been by any natural powers. It must be highly vain and temerarious in us who scarce know any thing, to decide on things utterly unknown: all which I do not repeat, as if I would persuade persons into a belief of old women's fables, the empty fictions of idle people, or the foolish imaginations of the credulous. I am too sensible that these matters are rarely credited by the wise, commonly by the ignorant, and are so much the less regarded, by how much we are the more prudent and cautious not to be imposed upon. In effect, the true *Magi* never pretended they could foretell things to come; discover things hidden; raise or fix the passions on any object of pleasure; keep off harms; communi-

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cate virtue; create, remove, or sooth diseases, by means of numbers, words, signs, figures, inarticulate murmurs, verses, images, looks, or injection; change themselves or others into other shapes; render any person, though present, invisible; be convey'd at pleasure through the air; walk on the water; give life, sense, motion, voice, and passion, to things inanimate; raise ghosts, dæmons, shadows, and dead bodies; call, drive away, or bind spirits; attain to honours; discover treasures; cause their money always to return back into their pockets; render their bodies invulnerable; overcome their enemies, or strikethem motionless at pleasure; command the elements, so that water or fire shall not hurt them; raise meteors in the atmosphere at command; tame the fiercest wild beasts by a charm; and produce diverting spectacles at a word speaking: these, and the like, we say, were not practised by the *Magi*; but are pretended to by doating old women, believ'd by the superstitious, and sometimes framed by the ill-minded, to deceive the imprudent, and bring them to their own purposes. Against all these did that excellent author *Roger Bacon* write with great force, to shew the nullity of such *magic*, and even that there never had been such in the world. But on the contrary, he seriously argues there are certain unknown and hidden powers lodg'd by the Creator in the nature of things, whereby as wonderful events may be produced as had ever been ascribed to the operations of devils: That such powers, 'tis true, are only discoverable by the endeavours of the most diligent and indefatigable enquirers, assisted by rational experiments purposely contrived, who, when they are discovered, compare and apply them to each other, and thus perform such things, as, by those who are ignorant of these powers, are supposed contrary to the laws of nature, and only owing to some preternatural power: this genuine knowledge therefore may properly be called natural magic. This I am now going to recommend as useful to human society, agreeable to the intelligent, and proper to display the glory of the Creator by the wonderfulness of his works; with which view I shall rehearse a few instances of the art derived from chemistry.

25. If any reputable author, ten centuries ago, had written that in his time a man publickly declared, before a multitude of witnesses, that a huge tower a few miles distant, would at a certain point of time rise up of its own accord, and immediately afterwards tumble into ruins; and that this accordingly happen'd, as he had foretold; would not all who read the account take it for a mere fable, or the effect of some supernatural power; and therefore denounce it, either owing to the intervention of the deity or the devil? Yet if only some one man had been acquainted with the power of gunpowder, and had repositied a competent quantity of it under the foundations of the tower, as is now sometimes practised, and had so disposed a clock, as that at the prefixed point of time it should cause a flint to strike on a steel, the sparks whereof might fall upon the powder; he would have wrought a miracle, which might have not only imposed on the credulity of the world, but even have moved the faith of the most knowing; so that he might afterwards have induced them to any thing. *Mabomet* or *Haly* would have been but fools to a man possessed of such a secret. But after the secret

is once known, the wonder ceaseth, and we all allow that feasible by natural means, which before we held to surpass any miracle of *magic* related in history. Nor that even the most intelligent in our days, can see into the cause of so extraordinary an effect; but we falsely imagine, that we understand, and are masters of things, which we frequently find to happen.

26. We may be able to foretell, that at a certain hour an earthquake shall be felt in a neighbouring spot of land; from whence a thick smoak shall ascend into the air, followed at last by eruptions of fire and flames. The hearers probably will laugh at the prediction; but how will they be confounded soon after, when the effect follows exactly as foretold? Taking a quantity of fresh iron filings, mixing it with an equal quantity of pure sulphur, working it with a little water into a paste; and laying fifty pound weight thereof in a hole dug under ground, a foot and half deep; covering the whole again with earth well ramm'd down: it will appear to our great astonishment, that such unpromising ingredients; as cold iron, and water, and unactive sulphur, will without other application, produce heat, smoke, fire, and flame, and shake the neighbouring ground (p).

27. We are told that the governor of a certain noble youth having endeavour'd by all his persuasions, but to no purpose, to reform the dissolute manners of his pupil, whereby he disgrace'd his birth and ancestors; despairing of doing any good, he had recourse to a chemical stratagem, which succeeded to his wish. As the graceless youth lay asleep in the same chamber with his governor, the latter rose privately in the middle of the night, and upon a board within the bed-tester, near the feet of the person asleep, wrote his name in large letters with the *English* phosphorus, adding three other words to admonish him to repent or expect present death. This done, he retires quietly to bed, and making a noise soon after wakes the youth, but seems himself all the while fast asleep; the other, startled with the noise, rears himself in his bed, and anxiously calls out to know the cause of the disturbance, to which he received no answer but feigned snoars; till, looking about, he sees, with the utmost horror, the blue blazing letters; upon which he calls his companion, and shows him the writing; who protesting that he could see nothing, help'd to increase his fright. Servants were then called to bring candles, upon the appearance whereof the letters disappear'd; they too denying that they saw any thing, he at last was surprized to find the writing vanished. The servants quit the room, leaving a candle which shone upon the board; the tutor staying with his frightened disciple, persuaded him to go to sleep, ascribing what had passed to a dream; and returning himself to bed, puts out the light: but the poor youth no sooner cast his eyes toward the fatal place, than the same letters appear'd anew, which occasions a new outcry: his tutor hereupon feigning himself affrighted, owns with trembling that he saw the letters, and takes that opportunity to advise his ward to obey the miracle, and repent in earnest: then bringing

(p) This Sir *Is. Newton* solves on the principle of attraction, which occasions that "even the gross body of sulphur powdered, and with an equal weight of iron filings, and a

" little water, made into a paste, acts upon the iron, and in five or six hours grows too hot to be touch'd, and emits a flame" *Opt.*

bringing in candles afresh, removes him into another room, sits up with him the rest of the night, and thus reclaims him. If this be really true, as I have frequently heard it related, it is an instance of natural magic borrow'd from chemistry; if it be only fictitious, yet all who converse in the art must allow that the same might be done by phosphorus.—If the phosphorus abovemention'd be duly mix'd and diluted with some soft oil, so that it may be smear'd over the skin of a man's body without burning it; then upon washing the face with some of this oil, it will shine in the dark to the amazement of the beholders: yet as soon as light is brought into the place, the spectacle disappears; but taking away the light again, the face will become luminous as before; than which scarce any thing can be seen more surprizing. The face, hands, hair, beard of a man thus anointed, appearing to those unacquainted with the thing, as I know not how angelical, or divine; this is a sufficient foundation for drawing the croud into a persuasion of any thing.

28. I must not forget an experiment which has often been publickly made, *viz.* that two cold liquors, upon mixing them together, immediately yield an intense heat, and burst out into a real and beautiful flame. This succeeds even at mid-day, to the amazement of the by-standers; but much more so in the dark, when the thick smoak, mixing with the dazzling light of the flames, gives the whole a terrible appearance. I scarce know of any thing among the magic wonders related by historians, so surprizing as this experiment; and yet the whole is performed by only taking two drachms of the one, and one of the other. If several pounds were used of each, an immense smoak and vehement flame would arise, which resisting all confinement, would seize and burn every thing inextinguishably; and immediately kill all that were near. Yet there is nothing more wonderful in this, than that if the mixture be made in an exhausted receiver, it will act with so much the more violence, and in a moment's time burst every thing, and fly about with a force greater than that of a whirlwind. This would be a very different fire from that raised by *Medea* on *Creusa's* head; since by this means a whole palace might be soon flung down, and burnt at once. Who ever heard of such terrible effects produced by magic power, as those which arise from balsam of sulphur terebinthinated, confined in a glass, and agitated by a fierce fire: it goes off with a loud crack, bursts the glass, and produces other such extraordinary effects, that among all the strange accounts I have met with of thunder and lightning, I don't remember any that may match it? An account of this *Hoffman* has given us (q); and in him you will meet with instances of things, that would have seem'd impossible in nature. He also relates an extraordinary event from spirit of wine, which a cooper had put in a strong wooden cask with lighted sulphur, and immediately well stop'd; upon which follow'd a dislosion of the vessel, with other effects almost incredible.—Again, how oft by the chemist's art have all kinds of colours been in a small space of time produced, destroyed, regenerated, and changed in a clear glass; after a manner perfectly surprizing, and seemingly beyond the power of magic, to those who are unacquainted in such matters.

(q) See *Fred. Hoffmanni Observat. Physico-chymic. Lib. iii. Observ. 15.*

29. But there is no end of these things; and it may suffice to have given these few instances of the sue of chemistry in natural magic. Give me leave to add a few reflections which occur on this matter. Mankind are so form'd by the Creator, as that when grown up, and especially if in a state of health, they have a power of perceiving certain changes and properties of the bodies around them, by means of organs contriv'd in their own frame; which undergoing some changes from external bodies, raise ideas thereof in the understanding, though after a manner little known. The first time such observation is made in a man's life, it fills him with wonder and amazement, striking him usually with an intense pleasure, and sometimes even disordering and unhinging his natural reason. A person who from his childhood had been quite blind by two cataracts, being happily couch'd for the same by a skillful operator, and thus brought in one moment to his sight, was so smit with the exquisite pleasure he felt upon viewing external object, that, according to Mr. Boyle's relation, he was on the point of swooning; which oblig'd them to tie up his eyes, and bring him to the light by slow degrees, admitting only a little at a time, by which becoming gradually accustomed to the thing, he was no longer affected as at first.—So the author of nature has taken care that the eyes of new-born infants have always their aqueous humour turbid, which grows transparent by degrees: the same has wisely stop't the external orifice of the *meatus auditorius* of infants with a kind of callous membrane, which separates the curved length from the duct, whereby sounds are so much augmented; lest the first noises should prove hurtful to them; but as they grow accustomed thereto, the thick cover falls off, and the *stentorian tube* is left in perfection, by reason a stronger sound may then be safely born. Hence appears the absurdity, upon the birth of princes, of exposing their tender organs to the light of a multitude of tapers, and discomposing them with the loud discharge of cannon around them. Let these be either omitted, or defer'd to some after-time.—But to return; 'tis well known how differently we are affected by usual things from those which are unusual; by which means we are led into an opinion that we know the causes of the former, which is an utter delusion owing to custom; but the latter generally appear miracullous, and we can hardly be induced to believe them owing to natural causes. When therefore any usual appearances occur, how little soever known by their causes, we make no difficulty of calling them natural things; but when other appearances turn up, to which we are utter strangers, we immediately proclaim them beyond, or above the power of nature. As often therefore as any physical *phenomena* arise not from those powers of nature which obtain in the bodies we are daily conversant among, but which are peculiar to some certain ones, which we had never observed before, we immediately suspect something of magic concern'd. A great general, the Count *de Furstenbourg*, going into an artificer's shop, where a person was filing metals to make tools by which a mixture was produced of iron filings with brass ones; ask'd the workman in a jocular way, what he would have to make a perfect separation of the particles of brass from those of the iron. A trifle, answers the workman; who hereupon applying a loadstone, the iron particles flew to it, leaving

leaving the brass ones behind it. The count immediately cried out magic, having never seen nor heard of any thing like it before; though otherwise a great soldier, and an able commander (r).

30. The like we are all forward to do upon seeing any unusual change in bodies, depending on some innate powers, which only show themselves when the bodies are prepared after some peculiar manner, either by art or chance. Of this it will be easy to produce instances. The cold salt of nitre well dried, and mix'd with half the quantity of pure oil of vitriol, and driven over by force of fire into a dry glass receiver, appears in form of a ruddy, volatile, fiery, acid, spirit, and becomes a liquor, which neither nature, nor art, produces after any other manner, except this invented by *Glauber*.—Divers vegetables, which were produced in the hottest climates, being extremely aromatic and acrimonious, yet if they be well boil'd with fair water, and the vapour kept in by a proper head, and cool'd by passing thro' a tin worm, fix'd in a vessel fill'd with cold water, will come out in form of water, and yield an oil, which subsiding by its weight under water, perfectly contains the virtues of the plant it was drawn from: and this is the only way of producing such liquor.—We have here therefore two factitious liquids, both cold; to one of which, *viz.* the oil, if to one part you pour twice as much of the other, *viz.* the spirit above-describ'd, a great ebullition will immediately arise, and the mixture will emit flames, which burn every thing (s).

31. Thus we see an effect, the cause whereof is lodg'd by God in these bodies; yet so as that it never becomes manifest to man, except by these contrivances, precisely thus applied: and hence the raising such an ebullition and flame only appears to be feasible on the three above-mention'd conditions, and never otherwise. By this it appears, how little men may safely pronounce concerning the powers of bodies, in whatsoever age they live: there being still more surprizing things hidden in the secret powers of nature, than all those which at that time had been already discover'd. Add, we frequently find that things known in former ages, but since lost, and not committed to writing, when they happen to be recovered, raise new admiration of the wonderful powers of nature: but enough on this head, which would lead me into an infinite detail, were I to insist on every point as it deserves.

32. The art of cookery, called also the culinary art, is one of those most useful to mankind; being employ'd in the preservation, changing, and ordering of foods; so as to make them fittest for the service of human life. This art, which provides for the healthy, as physic does for the sick, is doubtless

Cookery.

(r) See *Zwinger. Theatr.* 219.

(s) " Oil of vitriol being drawn off from
" its weight of nitre, and from both the in-
" gredients a compound spirit of nitre di-
" still'd; and two parts of this spirit poured
" on one part of oil of cloves, or caraway
" seeds, or of any ponderous oil of vegetable
" or animal substances, or oil of turpentine

" thicken'd with a little balsam of sulphur;
" the liquors grow so very hot in mixing, as
" presently to send up a vehemently burning
" flame: Does not this great and sudden heat
" argue that the two liquors mix with vio-
" lence, and that their parts in mixing run
" towards one another, with an accelerated
" motion, and clash with the greatest force?"

* *Newton, ubi supra.*

doubtless of great antiquity, and perhaps not much later than man himself; yet may still receive great improvements from the art of chemistry. The single acid spirit procur'd from sea-salt, being diluted with a due quantity of water, preserves flesh, fish, and other meats from putrefaction; gives them an agreeable taste, and fits them for easy digestion; and even turns the putrid effects of close weather into nutriment itself, and cures the diseases arising therefrom. Hence it is not easy to say, of how much advantage it is to seafaring people, who travel into other climes; where by reason of the excessive heats, they are forced to feed on putrefied water, stinking fish and flesh, rusty bacon and the like.

33. On this account *Glauber* deserves his praise, who wrote several treatises on the consolation of sailors, the prosperity of Germany, and the like; wherein he gives many things to this purpose; and teaches how persons may carry about with them in a little vial, without incumbrance, a liquor, of which a few drops will be of excellent salutary use: How from putrefied barley, now called malt, when dissolv'd, purify'd inspissated, and preserv'd from the air, a nutritious liquor may be made, a small quantity of which may serve for the support of life: How from this liquor and wheat-flower, biscuit may be made, which shall keep uncorrupted for the longest time, and prove an excellent food. *Boyle*, in his celebrated work of the usefulness of experimental philosophy, relates several easy ways, chiefly borrow'd from chemistry, for preserving flesh, fish, eggs, new, roasted or boil'd, for the longest space. The same art also affords us seasonings and pickles, to hinder, stop, or correct, the beginnings of putrefaction.

Art of wines.

34. The juice of berries, apples, and almost all summer-fruits, well ripen'd, being press'd, boil'd, and inspissated, affords a durable mass; a quantity of which being again diluted in water, even in the winter-season, yields its primitive flavour; whether it be prepared with sugar or without. The same juice being express'd in the vintage-time, works, froths, after which the lees subside; and thus is wine made, the whole process whereof is borrow'd from chemistry: the several defects also which befall wine, and the diseases arising in it, may be prevented or cured, by means drawn from chemistry. Thus if it begin to work again out of season, or turn sour, turbid, ropy, or the like, remedies are supplied by our art: or if it be desir'd to make vinegar of wine, the same art will furnish a method. It also teaches to prepare the same from any other pulpy fruit.

34. Grapes, cherries of all kinds, gooseberries, barberries, raspberries, elderberries, pears, apples, and plumbs, though so different in kind, may yet all be so manag'd by a skilful chemist, as to yield a vinous liquor; which with a little help, becomes nearly of the same flavour and strength; being in reality always of the same nature. So, for instance, the first liquor which rises from them, by a moderate fire, is always spirituous, inflammable, and miscible with water; and this liquor, if well purified by the chemists art, will always be found the same, from whichsoever of the above-mention'd fruits it was procured. Hence the happy island of *Great Britain* has small reason to complain, that her otherwise fruitful soil does not ripen grapes to so much advantage; since indulgent nature has furnished her with apples,
from

from whence, by an easy method, wine is made, which may vie, both in fragrantcy of smell, and pleasantness of taste, with the best wines of *France*, *Spain*, or *Italy*. The *Dutch* rarely make any good wine of their grapes; but of their currant-berries, gooseberries, and green elder berries, they make wines nothing inferior to the produce of the hotter climates. Lastly, herbs themselves, by fermentation, will yield a spirit; which though less in quantity, yet as to strength is little inferior to that procured from the richer subjects. All these being duly prepared, we are taught by chemistry to smoak them with burnt sulphur; in order to prevent their working a-new, as well as to preserve their taste from turning flat and vapid. Chemistry also teaches us to correct their too great austerity, by a small mixture of salt of burnt lees of wine; if too sharp or sour, the remedy is to add a proper quantity of crabs eyes or chalk in powder. A vile practice formerly obtain'd, which has since been severely, but justly punished, of tempering the rough sour *Rhenish* wines with lead, which gave them a grateful luscious richness, but subjected the drinkers to an incurable palsy: this too was a discovery of chemistry.

35. The countries which do not afford wine were taught, by *Isis* and *Osiris*, *Brewing*, a manner of preparing beer from corn; which was appositely denominated *Cereris vinum*, or the wine of *Ceres*. Accordingly, *Corn. Tacitus* relates, that the ancient *Germans* made a wine of corrupted corn. This art does so immediately belong to chemistry, that both of them had their rise from the same country, viz. *Egypt*. And *Basil Valentine* has given the whole doctrine of alchemy, in the single description of brewing, or the manner of preparing beer; which he traces minutely thro' all its branches, and delivers with no less accuracy than elegance (1). In effect, as wine and beer differ so little from

(1) *Matthiolus* takes the *zythum*, and *curmi*, to be the same with the beer or ale drink in *England*, *Germany*, &c. and that the only difference between the *zythum* and *curmi* lay in the manner of the preparation, which render'd them either weaker or stronger. In a famous dispute at *Paris*, in the year 1688, on the subject of the bakers using the yeast of ale and beer to leaven their dough, *Mess. Patin, Brayer, Blondel, and Courtois*, speak of that liquor in the following terms: "Beer," says *Corn. Tacitus*, that unhappy beverage, "made of hops, and wheat or barley, corrupted with damaged water, was no sooner discover'd than it was condemn'd by *Dioscorides, Galen*, and other of the greatest physicians. They all charge it with prejudicing the head, nerves, and membranous parts, of vitiating the animal juices, and of causing a more obstinate and painful drunkenness than wine." Other physicians vindicated it, particularly *Mess. Perrault, and Rainfant*; who, among other things, insisted that "the hop was not a noxious herb, but "on the contrary, had apparently the faculty

"of cleansing the blood, and removing obstructions; and that it was added to the modern beers to correct the ill qualities charged on the beer of the ancients, which differed from ours, in that it was made without hops."

In order for brewing, the barley is first to be made into malt; which is done by putting it into a cistern full of water wherein it may steep, for a longer or less time, as the weather is more or less cold; two days and nights sufficing in hot weather, and five or six in extremely cold: when sufficiently steep'd, the water is drain'd off, for twelve or twenty hours; then, being taken out, it is couched or heaped up into one or two heaps, and turn'd every five or six hours, the outermost part inwards, and the bottom upwards. As it comes or sprouts, it is spread thinner to cool, and prevent its coming too fast: when come, it is spread very thin, and turn'd twelve or twenty times a day till the sprout is dead: then it is again thicken'd on the floor, and turn'd as before; great care being taken that it neither mould nor become *acrospired*, that

from each other; what we have above related, concerning the use of chemistry in the history of wine, may be easily applied to the art of brewing.

36. By all that I have hitherto delivered, it appears, that chemistry is of great use and extent thro' all, or at least the chief of the mechanical arts: so that they who cultivate them might truly be called artificers, and make incredible improvements in their several provinces, if at the same time they were skilled in chemistry. Consequently there are many and weighty reasons to induce men to superadd chemistry to all the other sciences employed in the consideration or changing of bodies; and lastly carefully to observe, and faithfully write down, such effects as arise therefrom, to be afterwards reduced into order, and made publick: that by a number of contributions, thus brought from all quarters, the arts may at length be brought to perfection. What was in my power, I have endeavoured to perform in this undertaking; wherein, tho' I make no great advances, I am of some use; as I have set an example of labour before you, which, with the advantage of genius, may lead you on to make much greater discoveries.

Alchemy.

37. I come now to add a few, but candid and ingenuous considerations, on the great use of chemistry in alchemy. To speak my mind freely, I have not met any writers on natural philosophy, who tread of the nature of bodies, and the manner of changing them, so profoundly, or explain'd them so clearly, as those called alchemists. To be convinced of this, read carefully their genuine writings: for instance, that piece of *Raymund Lully*, which he entitles *Experiments*; you will find him with the utmost clearness and simplicity, relating experiments, which explain the nature and actions of animals, vegetables, and fossils. After this, you will hardly be able to name an author, wherein physical things are treated of to so much advantage.

38. The bodies, which chemistry resolves before our eyes, afford demonstrations which call for our assent, infinitely more cogently than any words could do; by these we do what we say, and what we teach we perform: In-somuch, that these writers seem to have attempted to build that body of philosophy, wish'd for by the great Lord *Bacon*; viz. a philosophy, which should lay down such powers of bodies, as the bodies themselves, when present

is, that the blade don't grow out at the end opposite to the root, or the malt come and sprout at both ends. The preparation is finished with drying it on the kiln, by spreading it on a hair-cloth, or a tin bottom full of holes, over a brisk turf or charcoal fire; stirring and turning it from time to time.

Now to proceed to the operation of brewing itself; they boil a quantity of water, and pouring enough of it upon the malt, in a mashing tub, to wet the malt as stiff as it can be well rowed about; after standing a quarter of an hour, another portion of water is added, and the sowing repeated: lastly, the full quantity of wa-

ter is added, according to the intended strength of the beer or ale. The whole having stood two or three hours, is drawn off into a receiver, and fresh water thrown on for a second wort; which is to be cooler, and to stand less time than the former. The two worts being mix'd, and the hops added, the whole is put into a copper well covered, and clos'd, there to boil an hour or two. Which done, the liquor is let into a receiver, and the hops strain'd therefrom: when cold, the yeast is added, and after fermenting or working, it remains to be tun'd up.

present, really exhibit effects to warrant; and consequently should assign such causes of things, as being given, will readily produce the things themselves: so that when it pleased it could do what it taught.

39. They laugh'd at those subtle universal causes, sought for only by speculation; the knowledge whereof did not render the inquirers more fit for effecting any thing, and of which the schoolmen obtruded more than enough. Hence they are continually inculcating, that man cannot by any art go beyond the powers impress'd by the Creator on bodies; of which powers such as are of necessary use to life, are obvious enough; but others lie less apparent, and are only revealed to those who seek them with great labour and industry, but that both are equally natural. That a man, therefore, possessed of all knowledge of things, both past and to come, would never be able to create, or make the least thing; for instance, a grain of mustard-seed; or produce it out of matter, which was not mustard-seed before. That wise men observe the works of nature as they offer themselves, and then by experiments endeavour to learn the laws; which the Creator has impressed on his work, and in what manner each thing, according to its peculiar nature, arises, is produced, or perfected; the principal of which laws is, that all things arise from other similar pre-existent ones; plants from plants, animals from animals, and fossils from fossils. That all power of propagating is contained in the seminal matter alone; which converts every crude thing it takes, into its own form, and assimilates it to itself. That to have an offspring from this semen always requires a male father, and female mother; so that nothing is ever produced without the natural copulation of these two. A prolific seed being given, lodg'd duly in a *matrix* intended for it, and supplied and cherished with due food and warmth for a proper time, an offspring arises like the parent: But if these be disturbed, an abortion will arise, instead of the thing desired. So that since the creation was completed, no new thing can possibly arise; but only similar things to those already in being are produced from them by means of seeds. That after this manner any created being may be multiplied *ad infinitum*, supposing, we mean, a proper seed. So that the whole earth, for instance, might be cover'd with fennel, if the seeds it yields yearly were sown again, and duly cultivated. They have also observed, that certain of the more simple bodies have ordinarily no seminal power, and consequently do not increase nor transmute others into their own nature; but either serve for giving motion to other bodies, as fire; or as a vehicle for conveyance of the nutriment, as water; or to give firmness and solidity to bodies, as in true and pure earth: All which being found, by a multitude of experiments, to obtain throughout all nature; they conclude, by parity of reason, that the same must also obtain in fossils. For, the great simplicity of the constitution of these, excluded all organical structure of seed; yet there was found some innate power, whereby they were able to prepare and apply their proper nutriment, and thus continually propagate themselves. They also taught, that the spirits, called presiding spirits, sealed up in metals, do not indeed appear in the dead metals, but becomes manifest in them when resolved, opened and revived; and thus produce obvious and extraordinary effects.

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They further teach, that something like marriage and generation obtains here; there being an impregnating male, and secundified female, by whose genital power a propagation *sui generis* is effected in living metals. Nor are they silent on the manner wherein living metals may be made, with what fire to be governed, in what proportion mixed, and with what pabulum fed, that they may be perpetually multiplied. They add also, that metals alone, by reason of their extreme simplicity, admit of being produced in the shortest time, from a heavy mercurial fluid, and a fixing seminal sulphurous power, intimately mixed by force of fire, and thus united together in an indissoluble bond, so that mercury, or *argentum vivum*, does the office of mother, and *sol vivus*, that of father: that, after this manner, what is performed in the bosom of the earth by subterraneous fire in a long series of years, may here be effected instantaneously, in metals properly vivified by art. They allow also, that among animals and vegetables, this power of generation is always limited by its proper time, which is prescribed by nature: that it could not possibly be otherwise, by reason of the smallness of the seminal fabrick, and the numerous different parts, out of which it is intricately composed; as also by reason the live spark, or embryo, in the centre of the prolific sulphur, is so easily spoil'd. But at the same time they advance, that in the purer metals, as gold and silver, and the mother of these, mercury, the parts are so similar, that every minute particle is of the same nature as the largest mass: that they are likewise so immutable, as not to be corrupted either by a small, or even the greatest fire. That the prolific virtue, therefore, of the seed resides in the fire; and thence acts very speedily, and in a moment's time assimilates a convenient mercurial matter to itself: and that on this principle it is, that metals may be generated or multiplied; and that the philosopher's stone may be made; concerning which last, if I were ask'd my opinion, I should answer, that the wise *Socrates*, after reading a most abstruse book of *Heracitus*, being ask'd what he thought of it; replied, that where he understood it, he found it excellent, and believ'd it to be so in those other parts he could not comprehend, which required the greatest penetration to come at. So where-ever I understand the alchemists, I find them describe the truth in the most simple and naked terms, without deceiving us, or being deceived themselves. When therefore I come to places, where I do not comprehend the meaning; why should I charge them with falsehood, who have shewn themselves so much better skill'd in the art than myself; from whom I have learnt many things, in those parts of their writings where they thought proper to speak plain? It is said when they come to reveal the perfection of the art, they then only write that the art is true, in order to animate others to the pursuit of it; but that they may not publish a secret, capable of being abused to such ill purposes, that it is enough for them to point out the way, and guard from error. I therefore rather lay the blame on my own ignorance than on their vanity. Yet I have often doubted, upon reading their secrets, whether these skillful persons, after they had discovered so many extraordinary things by naked observations, might not by a too great quickness of apprehension anticipate, and relate things for facts, which they conclude might be

be done; or even must of necessity have been done, if they had persisted in the pursuit. 'Tis certain a very grave alchemist, *Alexander Suchiben*, a disciple of *Paracelsus*, and a zealot in defending his doctrine, had tried so many things to so little purpose, that he concludes, at the end of his treatise of antimony, that all the philosophers, the principal of whom he there recites, had died before they brought their speculations to an issue. If this be the case, which I shall not pretend to determine, we are nevertheless exceedingly obliged to them for the immense pains they have been at, in discovering, and handing to us, so many difficult physical truths: Inasmuch, that Lord *Bacon* justly compares them to a father, who on his death-bed inform'd his lazy sons, of a sum of money which he had hid under ground in his garden. After his death they went to digging, in hopes of finding the treasure, and tho' they missed their aim, for in reality there was none hid, yet they sufficiently enrich'd themselves, by the large crop which the ground, in consequence of this tillage, produced. Thus much I have long ago had a mind to say, concerning the knowledge of the true alchemists in physics; lest such skilful artists should be condemn'd by incompetent judges.—Now the chief things which the alchemists promise are as follow:

40. To make the philosophers stone; a little quantity whereof cast upon metals in fusion, shall immediately convert all the true mercurial part of the metal into pure gold; better than any that is dug out of the mines, or perfected by the refiner's art: whilst that part of the melted metal, which was not mercury, is immediately burnt and blow'd away. This stone is said to be equal in weight to gold, brittle like glass, of a deep red colour, and melting like wax by the fire.

41. To make the like stone for silver, which shall convert all metals, except gold and silver, into the finest silver.

42. To exalt and perfect the philosophers stone to such a degree, as that when projected upon a quantity of gold, melted by the fire, it may convert the whole substance into philosopher's stone.

43. To exalt the same still further, so as that being projected upon pure quicksilver, it shall convert the whole into philosophers stone.

44. To discover an artificial body of such virtue and efficacy, as that being applied to a body of any of the three kingdoms, it shall improve its natural inherent virtue, so as to make it the most perfect thing in its kind. Thus, for instance, if applied in the human body, it will become an universal medicine, and make such a change both in the solid and fluid parts thereof, as shall render it perfectly sound, and even maintain it in that state, till the parts being slowly wore away and spent, death gently, and without any struggle, takes possession. The same it would also do in any other animal; and something like it even in plants themselves, if convey'd into their roots, and increase their fertility to a great degree.—Hence this wonder-working figment, is by them called the universal ferment.

45. To make precious stones, perfectly like the native ones.

46. To ripen the baser and more imperfect metals into gold, by continuing the coction and purification which nature had left short; for

they conceive that her view in all mines is to generate gold at last; viz. out of a mercurial matter elaborated by the fire, and refin'd by the density and pureness of the place; but if prevented either by the want of fire, or the looseness of the passages, or the mixture of foreign matters with the mercury, some crude heterogeneous matter is produced, which is still capable of being chang'd by fire. And such is the origin of all metals, (except gold and silver,) which may be further perfected by art, and converted into gold and silver. This last opinion however is not universally adopted by the alchemists, but only by particular ones. In reality, it appears that lead, tin, copper, and iron, are as perfect bodies in their kind, as gold in its kind; having always the same precise uniform nature. Accordingly, copper is of a disposition which renders it equally, if not more fit for various human and physical uses, than silver or gold themselves; notwithstanding that being less simple, it is more easily changed. Nor is there any probability, that such a metal, by any further coction of the fire, or separation of heterogeneous matters, should ever become gold, but only a most perfect copper; and the same also holds in the other metals. It must indeed be allowed, that those called the baser metals, when long detain'd in the fire, do always yield a little gold; but whether this had been generated there by maturation, or only disposed by the fire for separation, has not been proved; nor can I easily conceive how it comes that lead, which is the heaviest and most solid of all metals after gold, should be reputed so much further from the nature of gold than silver is held to be; since the *Adepti* unanimously agree, that the only standard in these matters is to be taken from the weight.

47. But enough is said on this head: we are always to remember, that the limits of nature are by no means to be defined by us; things are taken for impossible which are only unknown by the ignorant. The ancient writers spoke something of a perpetual fire, which was of a solid nature, and endured even under water; but it was exploded as an idle chimæra; though the same has since been actually discover'd by *Kraft*, and prepared by *Kunkel*, describ'd by *Boyle*, further explain'd by *Nieuwentijt*, and more amply still by *Hoffman*. *Roger Bacon's* artificial thunder and lightning were long laugh'd at, as empty fictions, but have been discover'd by *Schwartz* to be too true; and many of the other things related in the chapter of natural magic will appear much more incredible to those unacquainted with the experiments, than that lead should lose its natural form, and be converted into gold. Credulity is hurtful, so is incredulity: the business therefore of a wise man is to try all things, hold fast what is approv'd, never limit the power of God, nor assign bounds to nature.

48. Before I proceed to other matters, give me leave to rehearse all the apparatus, which the alchemists have declared to be necessary for performing their grand work. Gold, mercury, and fire, are by all allowed as requisite in the first and highest degree; then lead, iron, and antimony, as also nitre, and nitrous spirits extracted from it. A melting-pot, a glass mortar and pestle, a glass retort, with a receiver, and pure water; a furnace and bellows, a paper filtre, a glass, egg, and an *athanor*: Lastly, the whole expence necessary, not to exceed 200 florins; setting aside labour and trouble.

Of the INSTRUMENTS of Chemistry.

1. **H**AVING explain'd the subjects which chemistry is employ'd on; and, at the same time, shewn the chief uses it has in view in changing the same; it remains to relate the manner wherein these are to be obtain'd. In order to this I shall begin with the instruments which are always required when any thing is to be done by art. If a person asks me to shew him that which gives the bitter taste in wormwood, and desires it to be drawn separate from the other parts of the plant; I must first know that water, heated almost to a degree of boiling, will perfectly extract this bitter part; and if fresh be continually poured on, and, when well impregnated, pour'd off again, till after a number of repetitions the last water comes off as insipid as it went on, the plant will be left intirely destitute of bitterness, and the water contain all that was bitter in it.—In which instance it is evident, that water and fire were the instruments used in this operation.

2. In all arts which direct bodies to be chang'd, the name instrument is given to certain things capable of a particular motion; which being thence apply'd to the body intended to be chang'd, produces the requisite change therein: thus, in the present art, there are certain bodies by whose means the requisite actions are produced. These, with the best chemists, we usually reduce to six principal ones; fire, water, air, earth, menstrooms, and utensils; which are to be well understood, in order to have a just notion of the operations performed by them. I shall therefore speak of each in the order wherein they are above-recited; beginning with fire, by reason no chemical operation ever was, or can be hereafter performed, to which fire does not contribute; and this cannot be so extensively said of the rest.



of

OF FIRE.

The wonderful
nature of fire.

1. SO great is the power, so extensive the action, and so wonderful the manner wherein fire acts; that it was antiently held and adored as the supreme God, by a nation reputed the wisest of all others. Thus some of the chemists having found its extraordinary force, took it for an uncreated being; and many of the most eminent among them, attributing all the knowledge they had acquired to this instrument, called themselves philosophers of fire; as thinking they could not be dignified by a higher title. There is, however, nothing more wonderful in the nature of fire, than that while it is the chief cause and principle of almost all the effects cognizable by our senses, yet itself is imperceptible by any sense; being so incomprehensible, by reason of its extreme minuteness, that it eludes our nicest research; so that with many it passes for a spirit rather than a body (u).

2.

(u) The doctrine of fire here laid down by our author, will appear new and extraordinary; at least among us, who have been used to consider fire in the light it is set by Lord Bacon, Mr. Boyle, and Sir I. Newton.

The great and fundamental difference in respect of the nature of fire, is, whether it be originally such, form'd thus by the Creator himself at the beginning of things; or whether it be mechanically producible from other bodies, by inducing some alteration in the particles thereof. Among the modern writers, Homberg, Boerhaave, the younger Lemery and s'Gravesande maintain the former: the latter is chiefly supported by the English authors.

Bacon, in his treatise *de forma calidi*, deduces from a great number of particulars, that heat, in bodies, is no other than motion; only a motion so and so circumstantiated: so that, to produce heat in a body, nothing is required but to excite a certain motion in the parts thereof.

Boyle seconds him, in an express treatise of the *Mechanical Origin of Heat and Cold*; and maintains the same doctrine, with new observations and experiments: As a specimen we shall here give one or two of them. Many more will come in the course of the chapter.

" In the production, says he, of heat, there appears nothing on the part either of the agent or patient, but motion, and its natural effects. When a smith briskly hammers a small piece of iron, the metal

" thereby becomes exceedingly hot; yet there is nothing to make it so, except the forcible motion of the hammer, impressing a vehement, and variously determined agitation, on the small parts of the iron; which being a cold body before, grows, by that super-induced commotion of its small parts, hot: First, in a more loose acceptation of the word; with regard to some other bodies, compared with which, it was cold before: then, sensibly hot; because this agitation surpasses that of the parts of our fingers: and in this instance, oftentimes, the hammer and anvil continue cold, after the operation; which shews, that the heat acquired by the iron, was not communicated by either of those implements, as heat; but produced in it by a motion, great enough strongly to agitate the parts of so small a body as the piece of iron, without being able to have the like effect upon so much greater masses of metal, as the hammer and the anvil. Though if the percussions were often, and briskly renewed, and the hammer were small, this also might be heated. Whence it is not necessary, that a body itself should be hot, to give heat.

" If a large nail be driven by a hammer into a plank of wood, it will receive several strokes on its head, e'er it grow hot; but when it is once driven to the head, a few strokes suffice to give it a considerable heat: for while, at every blow of the hammer, the nail enters further into the wood, the motion produced is chiefly progressive, and

2. It will be necessary therefore, that we be strictly on our guard, least in ^{To be care-} inquiring into the nature of a thing so deeply hid, we fall into error. ^{fully sought.} To this end we must rigidly abstain from all speculations, fram'd only in the mind, nor give the least credit to any, however plausible, hypothesis, or precarious opinion, unless we have a mind to be bewilder'd and lost. If, in supposing fire of a certain nature, we be mistaken, an error will spring herefrom, which will spread itself thro' all physics; by reason, as we have above hinted, that in the natural actions of all kinds of things, fire has always the chief share. In our enquiry, therefore, what fire is, it will be proper to conduct ourselves as if utterly ignorant of it; intirely rejecting all preconceived opinions relating to in. Our method must be that of the algebraists, who, when they seek an unknown thing, suppose nothing at all known in it; and that they may still keep this in mind, denote it by a character which signifies nothing; except that such a quantity is unknown, and thenceforth to be sought: and further, these strict retainers to truth, while they endeavour to attain a thing which they yet do not understand, suppose no properties in the unknown thing, except such as are given, or at least have been absolutely demonstrated before.

3. Such caution can never be more necessary than on the present occasion, ^{Not by hypo-} in regard the elements of fire are found every where; in the most solid gold, ^{thesis.} as well as in the most empty vacuum of an air-pump; being present equally and in the same quantity, in all bodies and spaces, as will be fully proved in the course of this chapter. Hence, in all physics, it is found exceedingly difficult perfectly to distinguish the very action of fire from that of other concurring causes; while yet the nature of fire is so very different from theirs, that to confound them together will introduce the utmost uncertainty and disorder.

4.

"and is of the whole nail, tending one way;
"but when that motion ceases, the impulse
"given by the stroke, being unable to drive
"the nail further on, or break it, must be
"spent in making a various, vehement, and
"intestine commotion of the parts among
"themselves; wherein the nature of heat
"consists*."

Agreeable to this, is the opinion of Sir
I. Newton, who conceives that "gross bo-
"dies may be converted into light by the a-
"gitation of their particles; and light, again,
"into gross bodies, by being fixed there-
"in†."

On the other hand, M. Homberg, in his
Essai du Souffre Principe, holds, "that the
"chemical principle, or element sulphur,
"which is supposed one of the simple, pri-
"mary pre-existent ingredients of all natural
"bodies, is real fire; and consequently that
"fire is coeval with body‡."

Dr. Gravesande goes on much the same
principle: "Fire, according to him, enters
"the composition of all bodies; is contained
"in all bodies; and may be separated, or
"procured from all bodies, by rubbing them
"against each other, and thus putting their
"fire in motion. But fire, he adds, is by
"no means generated by such motion||."

M. Lemery the younger agrees with these
two authors, in asserting this absolute, and
ingenerable nature of fire: But he extends it
further. Not contented to confine it as an
element to bodies, he endeavours to shew that
it is "equally diffused thro' all space, is pre-
"sent in all places, in the void spaces be-
"tween bodies, as well as in the insensible in-
"terstices between their parts**."

This last sentiment falls in with that of
Boerhaave; which will be more largely set
forth in what follows.

* *Mech. Product of heat and Cold.*
| *Elm. Phys. T. 2. c. 1.*

† *Optic. p. 318, & 349.*

‡ *Mem. de l'Acad. an. 1705*

•* *Mem. de l'Acad. an. 1713.*

*By reason of
the difficulties
attending.*

4. Another difficulty in the way of philosophers who study the nature of fire, is, that excessive minuteness of its constituent parts, which not only surpasses all other known bodies, but even penetrates to its solid, and even least particles that we can any way find. And hence so many different and absurd notions have gain'd ground among authors, who, of all things, appear to have studied the nature of fire with the greatest application. The errors sprung from this quarter have not only infected chemistry and natural philosophy, but also the art of medicine; as will easily appear, if we consider the strange opinions broach'd by physicians, concerning the innate heat, radical moisture, and the like matters, which arose wholly from this source.—Henceforth, therefore, we are to suppose we know nothing concerning fire, and are to conduct ourselves so, till we have obtain'd something certain of it.

*The signs of its
being present,
to be first en-
quired.*

5. Yet how solicitously soever we may endeavour to know nothing of it, we can no ways avoid being acquainted with some mark, by virtue of which all persons profess that they know there is, or is no fire in a certain place. 'Tis necessary that such mark or sign be obvious to the sense, and that all men be agreed of it; otherwise the word will convey no precise meaning at all. Such mark also must obtain every where, and be true at all times. Thus, though a person may say he does not know what thunder is, nor understand any thing concerning it, yet such person has something in his mind answering to that word, and knows at least thus much of it, that it makes a rumbling in the air; and thus using a word common to all persons, he means the same thing by it, nor of consequence will easily confound it with any other. So both the intelligent and the ignorant, provided they use the same language, upon hearing the word fire, immediately think of a certain thing; otherwise when the word is pronounced, it would have no other effect, than if spoken to an *Indian* or *African*.

*The requisite
condition of
these signs.*

6. This sign must also be so peculiar to fire, as that it can agree to no other thing; that when the sign is certainly found to be present, it may be an infallible indication, that fire is there. Likewise without this, it must leave us in doubt, which of the things denoted by it is then present.

7. Nor is it less necessary that such criterion be inseparable from fire, so as that fire may never be found any where without this mark necessarily attending it: For thus alone we shall discover that it is present; a mark of a thing being useless, if such things may be latent, and not discoverable thereby.

8. Lastly, it is requisite that such thing, which does the office of a sign be obvious to our senses, and affect them easily; in which case it will clearly indicate the degrees of increase, or decrease, wherein the fire in any given space, or body, is either augmented, diminished, or continues. If these three properties meet together in the criterion of fire, it may be made use of for our present purpose.

*The use of a
certain sign.*

9. If a mark be found, wherein the three above-mention'd conditions obtain, we may confide in it, and safely proceed to make experiments concerning the nature of fire; which, however latent, is known to be present by

by such sign; especially, if being thus assured of its presence, we make use of means purposely contrived for making discoveries in the hidden properties of fire. And it will be so much clear gain, if, by the way, any thing new and unexpected shall voluntarily offer itself. Both these manners may afford us facts, which we shall endeavour to connect by proper reasons, in order to discover the unknown nature of fire; nor need we fear falling into error, while we pursue this path, which is allow'd by all as the only true one for arriving at certainty in physics.

10. In the meanwhile I must own, that it is not easy to assign this mark, whereby fire is known to be present in whatever place, or in how small quantity soever; and the reason of the difficulty is, that on enquiry there appears to be an incredible quantity of real fire in those places, where every one imagines not only that there is no fire, but that the contrary thereof obtains. Thus in the most severe frosty seasons, and in the coldest masses of matter, fire will be shown to be present, and capable of being soon incited in an intense degree; yet does it not in the least discover itself by any sensible indication, it exerts no apparent action, nor produces any of the effects usually ascribed to it (*x*). I own, therefore, I do not pretend to exhibit any sign, whereby we may discover the presence of fire, in the smallest quantity; but only an indication, which may certainly discover it to be present, when in any quantity beyond the least; which is sufficient for my purpose. 'Tis my opinion, that nothing, either great or little, can be known in bodies, except by a mere comparison of such bodies to each other, or to some common measure; so, in the present case, we have no sign whereby to determine how much fire there is in a given place; but only how much more or less there is in one place than another: hence also it is not easy to determine any thing concerning fire in the same individual moment of time; but the different degrees, which are observed at different times may be compared together.

11. Now looking round to discover such a sign, it occurs to me that the effects which are produced by fire alone, as oft as they are cognizable by our senses, are universally allow'd for proofs of the presence of fire: Wherefore these for the present we will admit for this purpose. For if those physical changes, which fire alone produces, be easily perceivable by the senses, they will afford us a mark whereby fire may be known to be present; and if those appearances always arise, wherever fire is produced, we shall have the very sign we wanted; nor need we be very solicitous, whether among such effects some may not be found, which sometimes arise from another cause; since, in the sequel of our inquiry, it will be easy to distinguish between those which are proper, and those which are only common. At present, therefore, we shall assume those which are usually ascribed by all men to fire; and shall afterwards examine each with care, in order to find the particular

(*x*) The younger *Lemery* observes, that ice is only a re-establishment of the parts of water in their natural state: that the mere absence of fire is sufficient to account for this re-establishment: and, lastly, that the fluidity of

water is a real fusion, like that of metals exposed to the fire; only differing in this, that a greater quantity of fire is necessary to the one than the other. *Mem. de l'Acad. Royal. An. 1709.*

ticular one we are in quest of. The principal I meet with are, 1. Heat. 2. Light. 3. Colour. 4. Expansion, or rarefaction both of fluid bodies and solid. 5. Burning, fusion, &c. each of which we shall consider in order.

Their examination, and first of heat.

12. Heat, then, is in the first place attributed to fire, and with good reason, as the two are connected by a very close tie; yet if we look near into the idea of heat, it will easily appear, that by this word men denote a certain sensation impressed on the mind, when their organs of feeling happen to undergo some change by the application of fire to them; but in this idea there is nothing contained that denotes either the action of fire, or the change of the feeling organ in the body: so that heat considered as perceived by the understanding, from whence alone it has its name, does not imply any thing corporeal, but only a mere change of thinking in the person that perceives. When I am warm'd, a clear and distinct species of sensation is produced in me; yet I learn nothing by that concerning fire, nor of the change in my body produced by it. When any of us grow warm, I would ask what we find; I suppose the answer will be a pleasing kind of sensation. Now, if this be compared with what physicians tell us is then doing in the body we shall find a vast diversity between them. They will inform us, that a fine fluid is then moved in the extreme capillary nerves, with a certain peculiar kind of motion; of which we never had the least notion, tho' we had a thousand times felt the impression of heat. But to estimate the degree of heat in the human body, it may be observed, that while the body and mind are both in order, and find heat agreeable to them, this degree of heat may be measured by the pleasure of the perception (*y*). When cold afterwards ensues, it denotes the heat first to be diminished, and afterwards extinct and absent. On the contrary, when the heat is increased, beyond that degree which gave pleasure, instead of an agreeable heat, we shall call it an offensive and painful one: in all which, there is nothing that can serve as any useful indication of fire. Add, that the degree of heat, to which we have long been accustomed, is not at all felt, agreeably to what we find on the like occasions: so that taking any degree less than the natural, or usual one, for none at all, we are continually deceiv'd. On the contrary, those who have been long exposed to the cold, are affected

(*y*) A body is only sensibly hot, when the degree of its heat exceeds that of our organs of sense; so that there may be a lucid body, without any sensible heat; and consequently, as heat is only a sensible quality, without any heat at all.

Heat, in the hot body, says *Gravesande*, is an agitation of the parts of the body, made by means of the fire contained in it; by such agitation a motion is produced in our bodies, which excites the idea of heat in our mind: so that heat in respect of us is nothing but that idea; and in the hot body, nothing but motion. If such motion expel the fire, in right lines, it gives us the idea of light; if in a various and irregular motion, only heat.

'Tis not very difficult to conceive, how fire should become sensible either to the feeling, or sight, by being thus determined in right lines. By such-determination, the vague, fluctuating corpuscles, are form'd into rays, and a train of them driven upon the organ in a constant succession. Hence, each subsequent one seconding the effort of the precedent one, the impression, by such a series of augmentations, at length is felt. Thus the air, wherewith we are every way surrounded, if left at liberty, is not perceived; but if its particles be driven or directed in a stream, whether by a pair of bellows, or any other cause that excites a wind, the impression it makes will be very sensible.

pected by it very differently from ourselves. It has been often observed, that subterraneous places afford a cool retreat, in the scorching heat of the dog-days; yet in the winter afford a no less grateful warmth in the severest colds: whence it was falsely inferred, that places under-ground are hot in the winter's frost, and cool in the summer's heat, and thus undergo a kind of *Antiperistasis*: whereas 'tis certain that the deepest vaults are hottest in summer, and coldest in winter; but that if they were dug beyond a certain degree of depth, they would then remain nearly of the same degree of heat. From all which it appears, that no certain measure can be had from heat, to determine the quantity of fire. This may be further confirmed by a matter of great moment in physic: when, in close sultry weather, occasion'd by the sun's being reflected, or refracted by the clouds, the heat becomes intolerable and suffocating; if thunder and lightning soon ensue, attended by severe showers, and sometimes even with hail, the effect is, that the air presently appears excessively cold, and men shake and tremble by the sudden change, as if smitten with a severe frost. And yet, I speak from experience, the air, which then seems so very cold, is in reality so hot, that if it should immediately succeed a sharp frost, it would destroy us by the extremity of heat: for if a room in pinching frost be heated to a degree, only equal to that of the atmosphere after such a thunder-storm in August, no person coming out of the cold air into such a room would be able to endure the heat, but would quickly faint away. — From all which we learn, that heat is no certain mark for determining fire.

13. Philosophers, therefore, think light may be used as an infallible proof of the presence of fire; for that being as it were the daughter of fire, it must be a just representative of its father; and in effect the more vigorously this noble creature diffuses its rays, the greater quantity of fire is usually supposed to prevail. And again, as the brightness of light decreases, fire is held to be diminished in equal proportion; consequently, this may be laid down as the *criterion* of fire. But they who argue thus, are little acquainted with experiments. If iron be taken out of the fire before it is red-hot, but very near approaching thereto, and thus held in a dark place, it will emit no light; and yet if you touch an animal with it, it will yield a hissing noise, a smell of burning, and even consume the creature to the bone, and the bone itself: or lay it on dry wood, and it will raise sparks and flame: so much fire may there be without any light. On the contrary, if you receive the image of the full moon in her meridian, on a clear winter's night, on a concave *speculum* made of a solid polished metalline substance; and this image be than received on a white paper, placed in the *focus* of the *speculum*, you will find the light exceedingly intense, and scarce tolerable to the strongest eyes; yet the centre of the *focus* is all the while extremely cold. The famous Dr. Hook, a man framed by nature for inventing experiments, having brought the rays of the full moon into a *focus*, by a glass convex on both sides, found, that though the light appear'd extremely bright on the paper, yet an excellent thermometer being applied to the same *focus*, gave not the least indication of heat or fire: and

Next, light.

the same was confirmed by *Tschirnhausen's* burning-glasses at *Paris* (2). Lastly, in *M. Viller's Speculum*, if the *focus* remain in the air, without any opake body to fix on, no sign of light will appear therein, even though the sun act with all his force; unless a person should have the imprudence to oppose his own body directly in the way, which must instantly destroy him: there being all the while a most vehement fire in the place, which in a moment's time melts even stones themselves. After this no person, we suppose, will measure the degree of fire by that of light; since, by these instances, it appears, that the most powerful fire may be without the least appearances of light, and the strongest light without producing the least heat. We need not say much concerning colour, which is only the reflection of light, variously chang'd by opake bodies, or even is light itself; since after having shewn that light itself is no true characteristic of fire, no body will imagine that colours can be so (a).

And colours.

Then the other effects of fire.

14. It will be necessary to examine the other effects of fire, in hopes that among them, we may find some one, which will enable us to discover and estimate the presence and quantity of this active element. But the more solicitously I look about, still the more I despair; so contrary and unpromising does every thing appear. If we think of its attenuating powers, it is immediately suggested, that many things are also inspissated by fire. If we next pitch on its power of binding, we presently recollect that it also dissolves many bodies. If on its faculty of separating things into different parts, 'tis easily alledged, that fire also combines many things, scarce capable of being intimately mix'd any other way; as we find in the making of glass and the mixing of iron and gold. Not to pursue so very copious a subject, I shall only add, that scarce any effect of fire can be assign'd, which it is found to have in a multitude of bodies; but in some other bodies it will be found to have the very contrary thereof. It may be asked then, is there no effect of this wonderful cause which obtains always, and every where the same, being also utterly inseparable from fire, and not variable by objects? I should believe there is such a one; and so far as I have been able to trace the footsteps of nature, there is only one. For on a careful inquiry, I do not

(2) See *Mem. de l'Acad. an. 1699. p. 110.*

(a) Natural bodies only become of different colours, as surfaces are disposed to reflect differently coloured rays; and a body appears of the colour which arises from the mixture of the rays reflected by it. Thus placing two bodies, *e. gr.* a red and a blue one in the dark, where neither of 'em is visible; and enlightning 'em successively by rays transmitted thro' a prism; they will then be seen, and each of the sorts of colour'd rays, will be reflected from each: but the red rays will be much the most copiously reflected from the red body, and the blue from the blue. And enlightning 'em both with only one sort of rays, *e. gr.* red ones; the red object will be very vivid, and the blue scarce visible.

To determine the precise constitution of the surface of bodies, whereon their colour depends; it is to be observed, that the smallest particles of all bodies are found to be transparent; and that they are separated by a medium of a different density from the particles themselves: and hence, in the surface of every colour'd body, we may conceive innumerable, small thin lamellæ, or plates. But it is demonstrated of such plates, and consequently of the surfaces of bodies, that their colour depends on the thickness, and density of the parts or plates in the surface, between the pores thereof; that the colour is so much the more vivid and homogeneous, as the plates or parts are thinner: and that, *ceteris paribus*, the said parts are the thickest, when red; and thinnest, when violet.

not find any body, to which we may not apply that which all men call fire, whether solar, culinary, or subterraneous; and all such bodies to which fire is thus applied, without one exception, are hereby render'd bigger, swell, and rarify, yet without any observable difference in their weight. This e-^{Rarification}qually and uniformly obtains in solid bodies, and fluid, hard, and soft, ^{the sign of}light, and ponderous. In the mean while it always appears, that two bo-^{heat.}dies of the same weight and bulk, one whereof is solid, the other fluid, differ from each other in this, that the fluid one is more expanded by the same fire, and the solid one less: at least this law obtains in all the bodies which I have had occasion to try. For this reason fluids are more fit for the office of judging of the presence of fire by rarification, than solids are. I have further found, that the lighter fluids always rarify more by the same fire, than the denser kind. On which account the rarification of the lightest fluid will affect the observers the most sensibly, and indicate the smallest increase, or diminution of the slenderest fire. Of this I shall give an ocular demonstration. Take a chemical phial, whose ample spherical body ends in a slender cylindrical neck; the whole being filled with clear water, as high as the mark fix'd on the neck; now upon immersing this in an open vessel full of hot water, you will immediately perceive the water mount up the neck of the phial above the first mark, and the like it continues to do every moment, so long as the water is made hotter and hotter. Again, if, taking the phial out of this water, you immerse it in other hotter than the former, you will find it rise still higher in the neck of the phial. Lastly, upon applying it nearer and nearer to the fire, you find it dilate more and more in proportion; but upon removing it from the fire, you again see the water sink. This may be a sufficient proof, that fire dilates water, so as to make it take up more space when hot, than when cold, without any apparent increase of weight. Hence it also appears, that a solid glass vessel does not stretch or expand so much as water; since, in the present case, the vessel which before contain'd the water will hold it no longer; notwithstanding that it is heated equally therewith. Again, you may observe how nimbly the spirit of wine in another phial, upon plunging it in the same hot water, rises up the neck, so as to be ready to run over: hence we may infer, that spirit of wine, being lighter than water, rarifies more and quicker by the same fire than water itself. These slight and familiar experiments abundantly evince the point propos'd. It were to be wish'd the writers of hydrostatics had given us the comparative weights of all known fluids. By means of these I might have been able to give a general rule founded on them all, which at present I can only give as the result of a great number; viz. that the spaces of expansion produced by the same fire, are to each other, as the rarities of the bodies expanded; or in the reciprocal *ratio* of their densities. Now by the experiments which have been made they are found to follow in this order:

The

The Theory of CHEMISTRY.

The lightest fluid is the *vacuum* in the *Torricellian* tube.

Then the vacuum in an air-pump.

Then air.

Alcohol.

Pure petrol (*b*).

Spirit of turpentine.

Water.

Vinegar.

Aqua fortis.

Spirit of nitre.

Oil of vitriol.

Quicksilver (*c*).

15. Thus the dilatation of the lightest fluid may easily afford us a sure criterion of the presence of fire, and of its being either increased, or diminished; inasmuch as this effect has no dependance on our senses, (which are so easy to be deceived in these matters,) and therefore can hardly be liable to an error.

16. Again, this way shews very accurately the smallest increments, or decrements of the degree of fire, which I know no other way, yet discover'd of determining by experiment. Another advantage of this method is, that it may easily and readily be apply'd to use in all places, either within bodies, or without 'em, and this also at all times. Another considerable use is, that this expansion of bodies by heat, if it be performed in a glass hermetically sealed, cannot arise from any other physical cause hitherto known, but from fire alone; so that the thing desired is now found, *viz.* a true, certain, inseparable, peculiar, characteristic of fire; and this alone we shall use in the sequel for discovering the nature of fire; taking it for granted, that in all phenomena where this rarefaction is observed, there fire is discovering itself to us in proportion: by which we shall have an opportunity of examining fire in almost all its conditions, and of reasoning about its hidden nature, which discovers itself in all the experiments of this kind. I shall now proceed, step by step, through a beautiful field, of the most simple phenomena, till we arrive at the most remote and abstruse properties of fire, still proceeding from the more easy experiments to those less obvious and ordinary.

EXPERIMENT I.

Iron expands every way with heat.

17. Fire expands even the hardest bodies, in all their dimensions, so long as it is contained in them (*d*).

(*b*) Boyle, *Mechan. Qual.* 88.

(*c*) See Boyle's *Medicina Hydrostatica*.

(*d*) "Fire," says Dr. *s'Gravesande*, "naturally unites itself with bodies: and hence it is that a body brought near to the fire, grows hot; in which case it also expands or

17.
"swells; which expansion is not only observed in very solid bodies, but in those whose parts do not cohere; in which case they likewise acquire a great degree of elasticity, as is observed in air and vapours*."

Thus *s'Gravesande*: "All bodies are dilated
"by

* *Element. Phys.*

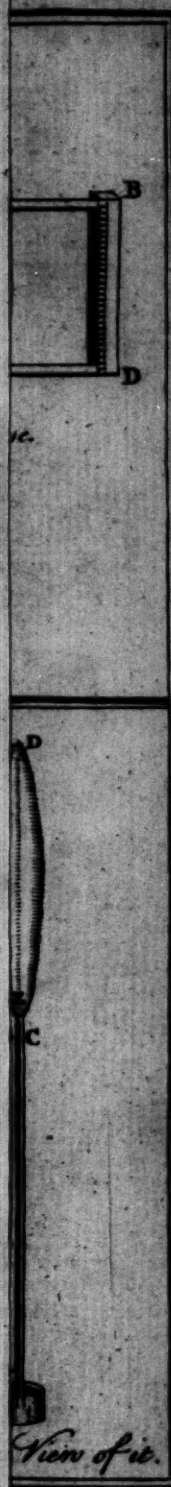
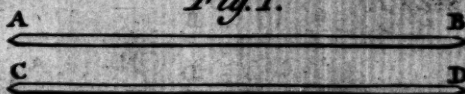


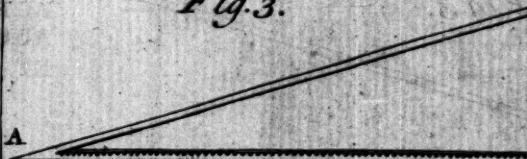
Plate I *see Pag. 215.*

Fig. 1.



AB. CD. *Two cylindrical Iron Rods 3 feet long.*
 EF. *An Iron Ring for them to pass through cold.*

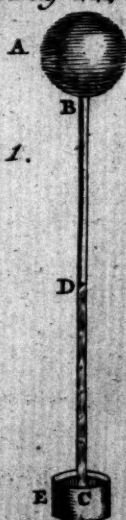
Fig. 3.



AB. *A Brass Ruler.*
 BC. *Another joined to the former perpendicular*
 AD. *A brass Hypothenuse moveable at A.*

Plate II *see Pag. 224.*

Fig. 1.

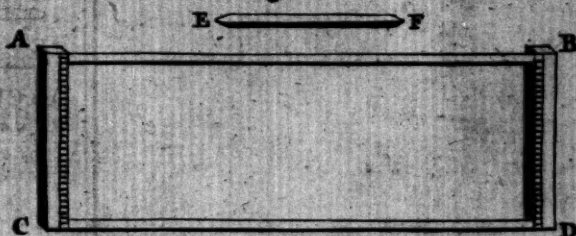


ABDC. *Drebbel's Air Thermometer.*
 A. *The Ball.*
 BD. *Part of the Stem fill'd with Air.*
 DC. *The remaining Part fill'd with the tinged L.*
 E. *A Vessel containing the Liquor.*



pendicularly.
at A.

Fig. 2.



AC.BD. Two parallel Brass Plates.
AB.CD. Two others moveable upon these.
EF. An Iron Rod.

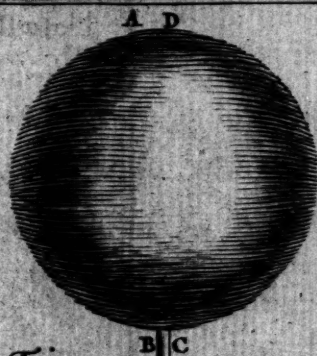


Fig. 2.

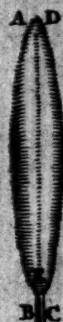


Fig. 3.

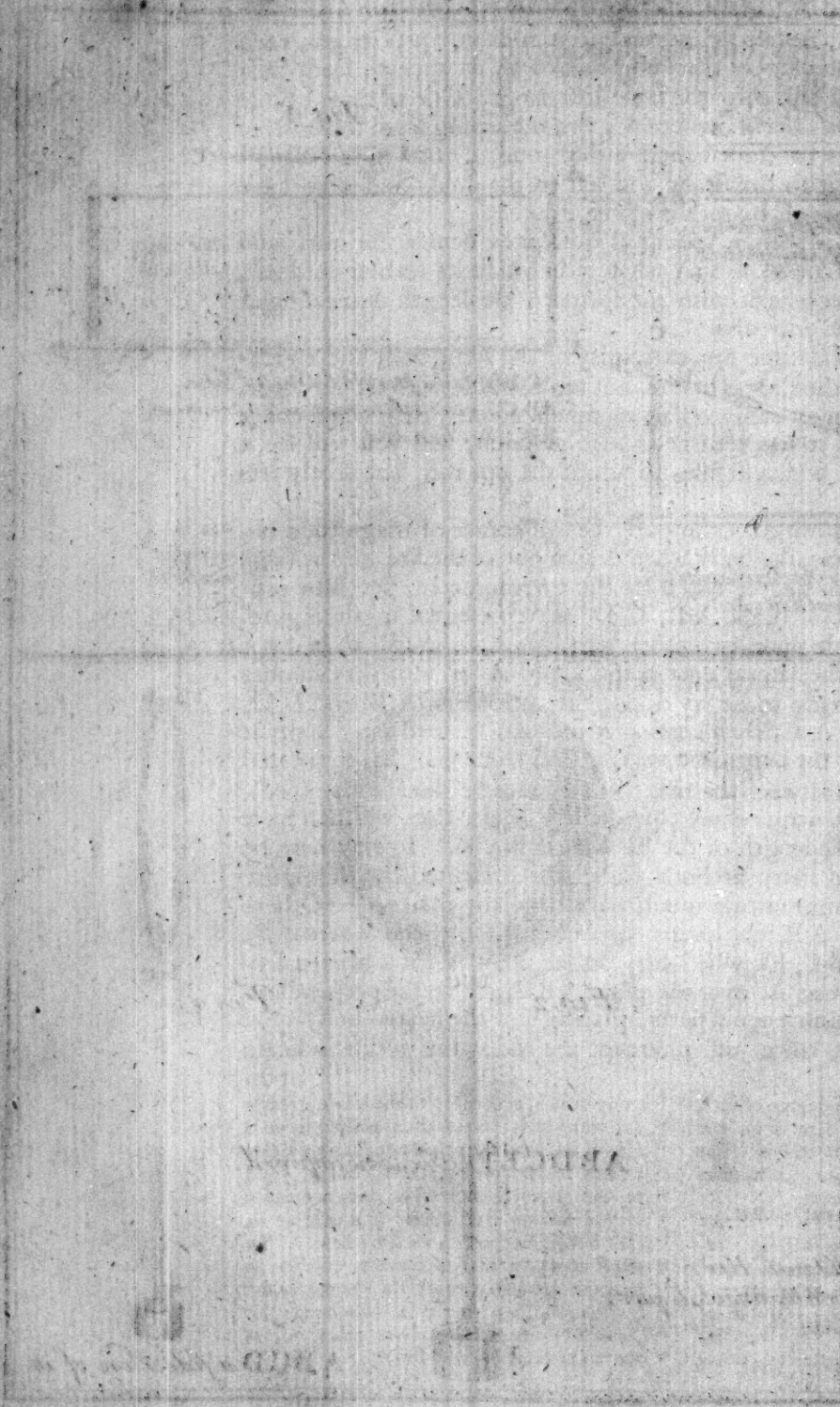
ABDCEF The same improv'd.

acter.

th Air.
be tinged Liquor.



ABCD a side View of it.



18. To shew this, I take two cylindrical iron rods of equal length, each being three foot, and likewise of the same thickness, as appears from this, that both of 'em will just pass thro' the same iron ring. One of these I place in the hollow tower of an *athanor*, wherein a fire is burning from the bottom to the top; after it has continued there a due time, I draw it out almost red-hot, and applying it to the other rod left in the cold, find it to have gained considerably in length by means of the fire.

19. Yet, every moment after taking it out, it evidently shrinks, and grows shorter again as it cools; so that when returned to its former coldness, it measures just the same length with the former: the length decreasing at the same rate as the heat decreases. *And contracts with cold.*

20. I now heat a second time the extremity of the same rod, and endeavour to pass it through the ring as before, but am not able with all my force, being become, as you may easily observe, much thicker than when cold; yet wait but a little, till it has returned to its coldness, and you will see it pass the ring as before; which refuses to admit the hot rod, but freely lets it pass when cold.

21. If any one have a mind to compute the difference of magnitude between red-hot iron, or the like body when drawn out of the fire, to the same when cooled to a certain degree noted by the thermometer; let him provide two parallel plates of brass, A B, C D, as represented in the figure. *The degrees of expansion measured.* See Pl. I. These plates are moveable upon two other lateral ones, so as still to be kept parallel to each other; the lateral ones being also divided into very minute parts. Take now the body to be try'd, and fitted between A B, and C D, by the side of the plate A C, then heating it red-hot, immediately apply it against the same A C, at the same time moving A B from C D, till the heated body be just intercepted between the two; which must be done with expedition, so as A C may not acquire any considerable heat: thus we shall have the difference between the length of the hot and cold rod. It may here be necessary to have the rod sharp at both ends, as represented by the figure E F, that it may not communicate much warmth to the plates.—Otherwise take a brass ruler A B, the longer the better, at the end whereof B, erect the perpendicular B C, likewise long; on the point A, fit a brazen hypotenuse A D, moveable at A, over the plain A B C, and let the perpendicular B C, be divided into minute equal parts; placing now the heated body upon A B, raise or lower A D, till it just intercept the rod: thus will it indicate

upon

“ by the action of fire; but the degree of such dilatation seems rather to depend on the motion, than on the quantity of fire. For bodies are expanded by rubbing, as well as the application of fire externally.”

“ From this expansion it follows, that the constituent particles of bodies, acquire a repelling force by the action of fire; in virtue whereof, they endeavour to recede from each other, with a tendency contrary to that of attraction. While this last force remains stronger than the other, the particles cohere

“ more or less, according to the less or greater degree of heat: when the repelling force is almost equal to the attraction, the particles before firmly join'd, scarce cohere, yield to the smallest impression, and are easily moved among each other: and thus it is, that a solid becomes a fluid by heat. The effect may be so increased in some bodies, as that the attracting force shall be overcome by the repelling force, in which case the particles fly from each other: and thus it is that heat volatilizes bodies †.”

* *Element. Phys.*

† *Id. ib.*

upon B C, the parts that express the difference, which will be found so much the greater, as A B, and B C, are the longer.

All bodies expand with heat.

22. It must here be observed, that this expansion of solid bodies by fire is general, and obtains after this manner in all the instances where observation has been made.

But differently according to their weights.

23. But you must not imagine, that it is thus great in all bodies. On the contrary, in the heaviest bodies it appears the least, supposing the fire the same; and in the rarer the greater, in such experiments as I have made; so that the rule is truly general. I shall content myself to have just indicated thus much; you will easily make further observations by the last instrument, and learn whether all the expansions of bodies, by the same fire, be to each other as their weights. I have been prevented from pursuing the search, by a multiplicity of business, and too scanty an allowance of time; but from what I have seen and done, I am inclined to believe, that among solid bodies the rarer they are, the more they expand; and the denser, the less.

And other properties.

24. But there are other causes which produce a variety in the quantity of the expansion, even beyond the density, which is measured by the weight. Having long been soliciting that industrious artist *Dan. Gab. Fabrenheit*, to furnish me with two thermometers; one made of the densest fluid, viz. mercury; the other of the rarest, viz. spirit of wine; and so contrived, as that they should always equally exhibit, in the same degree of heat, the rising excess of the contained liquor on the adjoining scale, which he ingeniously endeavour'd to effect accordingly; yet, when I came to try the agreement of these two thermometers, I found a difference, and discovered it to the maker, who ingenuously own'd the failing, though he did not then see the cause of it; but revolving it often in his mind, he at length discover'd, that the very glass made in *Bobemia, England and Holland*, expands more or less easily and readily by the same degree of heat: hence he inferr'd, that the instruments would answer, if both were made of the same kind of glass; but not if one were made of *Bobemian* glass, and the other of *Dutch*: because that sort of glass expands the least, which requires the intensest fire to melt it; while that sort which easily runs in the fire, dilates the more; supposing both acted on by the same degree of fire. How circumspect does nature require us to be, in order to discover truth in physical matters; and how often are we deceived by following a general rule? How different a thing is it to make use of the hasty conclusions of reason, from that slowness of science, which goes patiently on by cautious experiments?

Expansion the measure of heat.

25. The expansion also increases in proportion, as the quantity of fire received into the body is greater; so that the iron rod, for instance, when red-hot, is longer than the same rod when only hot, but not ignited; and is shortest of all after it has stood a long time in a cold atmosphere. Here I would recommend it to others to compare the length of iron (which of all metals bears the greatest heat before it run) when thoroughly ignited, so as to be ready to melt in a very cold season, with the length of the same iron, when returned to its coldest state; by which the effect is seen in all its extent.

Expansion remains in solids fused by heat.

26. As soon as iron is melted into a fluid matter, it appears to continue of the same bulk in the vessel it is melted in, even though the action of the fire be

be further increased by force of bellows: the reason seems to be, that it can receive no more fire into it; and consequently, is incapable of further expansion, by any force of vulgar fire. Yet metals, thus liquified, may be made to imbibe more fire, if this be collected to a *focus*, and directed upon 'em by means of a concave *speculum*, or a convex burning glass.

27. Thus we learn, that fire, even from the greatest degree of cold known to us, to the highest degree of heat, expands all the parts of the hardest body it is apply'd to, and removes 'em from their mutual contract on all sides: it likewise appears that this expansion, and the rarity of the body ensuing thereon, is successively increased, till at last the whole mass, if it be fusible, come to melt: so that in the whole course of the growing heat, the several parts of the heating body are perpetually receding from the centre of their respective masses, as well as the whole bulk.

28. Thus also we learn, that the particles of fire distributed through the mass, act every where with the same force upon the *molecule* which they possess; and that there is no body so extremely hard, but may be changed by the gentle action of the lightest fire, through its whole mass, so as no part of it shall remain unchang'd.

29. Now what is this expansion but a receding into other greater spaces than the former? From whence I conclude, that the parts were moving during the whole course of the operation: which further shews that fire moves all the parts of the hardest body, both internal and external; and this according to all its dimensions; and the more so, by how much the fire is more raised; till having at length reduced them all into a *fluor*, it shakes and mixes them with great violence.

30. Yet it may be doubted, whether fire has yet attenuated the mass so as that the parts now fluid are the elements of the body, while they retain their fluidity; and whether the particles of metals, thus liquified by fire, be so intimately mixed even to their minutest parts as that the like attenuation cannot be produced by any other means. The refiner's art, 'tis certain, shews us that a single grain of gold, if mixed with an hundred thousand grains of pure melted silver, so as that the two may run together, the gold will blend and incorporate itself so thoroughly with the silver, that if you afterwards cut the smallest grain from the mass, you will find in it the due proportion of gold and silver, *viz.* as 1 to 100000; and this *ad infinitum*; there being no limits to this faculty which gold has of dividing and distributing itself thro' silver. If this experiment be consider'd closely, we shall think it no way improbable, that the fire, while acting on the gold, in the whole course of its increase, from the greatest cold, was continually moving its elementary particles, so as to make them cohere less and less, till at last they become disunited, or set at liberty from each other, and thus move freely about.

31. 'Tis also the fire alone, which, while it continues to act with the same force, hinders the particles, as they touch one another, from clinging, or cohering again; for if the same fire be removed, they immediately coalesce and harden as before.

The particles of metal at fire, still retain an endeavour to unite again; as we see gold, silver, and the other metals, when fused, immediately collect themselves into a sphere, after the same manner, as mercury affects to form itself into a spherical figure, unless the weight of the parts should hinder. But this power cannot obtain its effect so long as the violence of the fire interposes.

Fusion alone fits metals to unite their separated parts. 33. Two pieces of gold can never be join'd with the tenacity peculiar to this metal, unless they be both divided to the last particles; viz. by melting them by the fire: For then, when cold again, they immediately recover their former ductility. And what has been spoke concerning metals, holds also in other simple bodies; as in fix'd salts, glass, and the like. From hence we also learn, that it is not only possible, but even is actually seen, that a body which appears perfectly hard and immovable, may be immediately so shaken in all its component elements, as that even the minutest particle in its whole mass shall not remain absolutely at rest.—All which points hitherto enumerated, follow so clearly from the consideration of the experiment above proposed, that no difficulty can arise therein: so that fire appears to act on the very intimate nature of bodies.

34. Henceforward, therefore, we need not wonder at what is sometimes known to happen, viz. that the strongest buildings tumble down in hot sultry weather, usually about noon-day, and without any wind.

Bodies not every where of the same size. 35. From this property of fire we also infer, that bodies become much bigger in all their dimensions in the torrid zones than in the frigid ones: and thus also are comparatively lighter in the former situation; as containing the same quantity of matter under a greater surface. By this means also their percussions are performed with the less force: and hence pendulums prepared in the frigid zones, grow longer in the torrid ones, and thus make their oscillations slower; by which means the best clocks are made to err. The like is found even in the same country at different times of the year, according to the different degrees of heat.

The laxity of bodies, what. 36. 'Tis with truth, therefore, it has been asserted in all ages, that bodies are chiefly loosen'd, and weaken'd by fire; for as those two words denote the condition of solid bodies, whereby they become disposed to be easily dissolved, by a weaker agent, into their parts; it is evident from what we have just shewn, that fire does this from its weakest degree, and that every step whereby it is increased, promotes the dissolution more and more; till at length there is no more firmness left, even in the hardest bodies, but they liquify and run. Accordingly, it appears by the history of all ages, that the inhabitants of *Asia* and *Africa*, who are exposed to the greatest action of the sun, have always been softer and weaker, and consequently more disposed to laziness and indolence. So in burning fevers, the excessive heat dissolves and enervates the whole body: the dried parts, it must be owned, do here grow stiff and rigid; but this is not owing to the fire considered as lodged in the solid parts, but considered as it evaporates the aqueous parts: In which sense alone, it can be truly said, that fire strengthens some bodies which were weak before.

EXPERIMENT II.

37. Cold, which is usually called the absence of fire, contracts hard bodies in all their dimensions, so long as it remains in them. This has been shewn so clearly in the former experiment, that it would be needless to give any further proof.----But from this you will give me leave to draw several conclusions.

38. All bodies of a solid structure are equally subject to this action of cold; nor has any been yet found, however dense and compact, but cold renders still denser; not even excepting diamonds, the hardest of all known bodies.

39. That as the degree of cold increases, this contraction is also increased; the former contraction still decreasing as the cold is less.

40. And what is further remarkable, this reduction of bodies into less space obtains even in hollow spheres, and orbicular *annuli*, towards the centre of the body, or the surface. Thus if this iron ring be cold, it will not admit the cylinder in my hand; but after it has been a little heated, lets it pass with ease. So this glass sphere, which terminates in a narrow cylindrical neck, when filled with a coloured liquor as high as the mark in the cylinder, and then plunged into a liquor much colder than its own, the coloured fluid at first rises very sensibly, but presently falls again; by reason the external cold, applied to the surface of the immersed sphere, before it penetrates to the liquor contain'd in it, first cools the glass, which contracting hereupon, drives the liquor out of the sphere into the neck, or pipe; but no sooner has the cold arrived at the body of the liquor itself, than it makes it contract, and thus sink again. From which experiment we learn the nature of this contraction; which resides, if I may so call it, in the intimate substance of bodies.----The same contraction, ensuing upon cold, is still more sensible in other hot vessels.

41. It appears, likewise, from all experiments, that this reduction of bodies into less space, always proceeds proportionably to the cold itself; thus is the bulk lessened, and the weight retained, though the comparative specific weight be increased: so that in severe cold weather, all bodies are found the less in bulk. But as no one can assign a body, wherein there is absolute cold, or in which there is no fire; hence it is also impossible to reduce any body, for instance an ounce of gold, into its least possible bulk. In the mean while, we must find the ratio of condensation, by that of the degrees of cold.

42. Hence, also, the mere absence of fire produces a motion still more wonderful in all solid bodies: I mean a motion in all, both the external and internal parts, by virtue whereof all the atoms of the body tend towards its centre, and by that means also draw nearer, and cohere faster together. If, therefore, cold were a meer privation of fire, the power which contracts the particles of a solid body, would be innate, or implanted in the nature of body itself; while the power that expands would depend upon the fire, and

consequently be something extrinsic, or superadded to bodies, and therefore violent. Accordingly, bodies would then endeavour to shrink into close masses, till they arrived at the *minima*, or least elements; when they would remain perfectly solid and quiescent: whereas, on the contrary, they are now continually shaken by fire, nor ever arrive at a state of rest: so that the end of cold is a state of absolute rest, between coherent particles; and the end of fire a perpetual agitation of dissolved particles (*e*).

43.

(*e*) Fire, thus being acknowledged the instrumental cause of all motion; it remains that itself be moved: nay, to move must be more natural, and immediate to fire, than to any other body; and, hence, some have ventured to make motion essential to fire: but as this is inconsistent with the notion of matter, which is defined to be inert, and passive; and as we shall hereafter shew that fire is material; we must rather agree, that the motion of fire itself is derived from some other higher, and more metaphysical cause. A property of perpetual mobility may indeed be superadded to the other properties of fire; but it has no natural, necessary connection with them: nor can it be maintained with them otherwise than by some extrinsic efficacy of a superior cause.

However, that it is by motion that fire produces its effects, is evident. And hence the action of fire cannot make any alteration in the elementary substance of bodies; for it is necessary, that what acts upon an object, be without that object; *i. e.* the fire must not penetrate the elementary parts, but only enter the pores and interstices of bodies: so that it does not seem capable of making those transmutations which Sir *Isaac Newton* ascribes to it; of which we shall speak hereafter.

In effect, as to all our purposes, it may perhaps be said, that fire is always in motion: take, for instance, fix several sorts of thermometers, and two vessels of water with sal-ammoniac mixed therein; and apply the thermometers thereto: the consequence will be, that the air being condensed in them, the spirit will descend in all: remove the vessels of water; and the air growing warmer, and so rarefying, the spirit will ascend again. So that the active force in air which produces so many effects, does really all arise from the fire contained in it.

Again, as all bodies placed in a very cold air, do, by degrees, grow cold, motionless, rigid, &c. tho' there be still some remains of fire; and in proportion as that is diminished, the effect is accelerated; it follows, that cold, *i. e.* a less degree of heat, is the effect of a less action of fire. And so all action apparently arises from the same source.

Tho' fire be the great cause of fluidity, and motion, yet is it frequently found in such small quantity, that, instead of fusing, or keeping bodies in a state of fusion, it becomes inclosed, and fixed therein, so as to remain, as it were, imprisoned, till some external cause come to its assistance, and open the cells which before detained it.

This is the case in quick-lime, as also in lead, tin, regulus of antimony, &c. when calcined: in which the younger *Lemery* observes two things: (1) That the fire thus inclosed, makes a sensible addition to the weight of the body; amounting sometimes to one tenth of the whole: And, (2) That during this imprisonment it still retains all the particular properties or characters of fire; as appears hence, that when once set at liberty again, it has all the effects of other fire. Thus, a stony or saline body being calcined, and water poured on them; that fluid is found sufficient, by its external impression, to break up the cells, and let the fire out: and upon this the water is rendered more or less warm, according to the quantity of fire lodged therein. Hence, also, it is, that as some of these bodies contain a deal of fire; and the slightest occasion is capable of disengaging it; upon applying them to the skin, they burn, and raise an eschar not unlike that of a live coal.

To this it is objected, that the particles of fire are only such in virtue of the rapid motion wherewith they are agitated; so that to suppose them fixed in the pores of a body, is to divest them at once of that which constituted them fire; and consequently, to disqualify them for producing the effects ascribed to them. To which *M. Lemery* answers, that though the rapid motion of fire do contribute very greatly to its effects; yet, the particular figure of its particles is to be considered withal. And though fire should be detain'd, and fixed in the substance of bodies; yet why should it fare worse than other fluids in the same circumstances? Water, for instance, is a fluid, whose fluidity depends, as already observed, on fire; and, consequently, is less fluid than fire: and yet, every day, water is inclosed in bodies of all sorts, without losing its fluidity,

or

43. It may be here asked, whether fire and cold do not seem the only things that affect the substance of bodies; others only affecting the parts thereof? Whether absolute rest in any space would not make the greatest cold? And whether there would not be rest in a place where there is absolutely no fire? *Heat and cold act strongly in all bodies.*

44. Hence also pendulums becoming shorter towards the poles of the earth make a greater number of vibrations in the same time; and the weights or bobs fasten'd to them, becoming thus also condensed, have a less surface *The figure of the earth from heat and cold.*

or any of the properties that characterize it. Add, that when water is froze, the motion of its parts is, doubtless, discontinued; and yet the figure of the particles remaining the same, it is ready to commence a fluid, as before, upon the least warmth. Lastly, though salt be allowed to be the matter of taste, and that it has certain properties, arising chiefly from the figure of its parts; yet, it only acts when dissolved; or, which amounts to the same, when it swims in a fluid proper to keep its parts in motion: yet it is not less salt, or less the matter of taste, when not in a state of dissolution. To despoil it of that quality, the figure of its parts must be alter'd.

As to what may be further objected of the impossibility of fixing so fine, subtle, penetrative, and active a matter as fire, within the spongy substance of a gross, porous body; it will be of no great weight, unless it can be proved, that the pores of the cells are bigger than the same. If it be insisted, again, that a body which could find its way into a solid body, might get out again the same way; and that as it only penetrated the body, inasmuch as its own corpuscles were smaller than the pores; so, the same pores must let it out again: it is answered, that the pores are not now in the same condition as before; the fire, in calcining, open'd, and dilated the pores; which, upon the fire's ceasing, must close, and contract again*.

"Tho' a great likeness might be expected," says Mr. Boyle, "between the particles of fire adhering to quick-lime, and those of highly rectified spirit of wine; yet I have not found, that the affusion of that spirit upon quick-lime produced any sensible heat, or visible dissolution of the lime, tho' it seem'd to be greedily suck'd in, as common water would have been. And I further tried, that if cold water were poured on the same lime, so drenched, there ensued no manifest heat; nor did the lump appear swell'd or broken, till some hours after; which seems to argue that the texture of the lime admitted some

"particles of the spirit of wine into some of its pores, which were either larger, or more fit, without admitting it into the most numerous, whereinto the liquor must be received, to be able suddenly to dissipate the corpuscles of lime into their minuter particles†."

"These phenomena seem to shew, that the disposition which lime has to grow hot with water, greatly depends on some peculiar texture; since the aqueous parts, which one would think capable of quenching most of the fiery atoms supposed to adhere to quick lime, did not near so much weaken the disposition of it to heat, as that access of the spirituous corpuscles; and their contexture with those of the lime, increased it‡."

"If, instead of cold water, you quench the lime with hot water, the ebullition will be, oftentimes, far greater than if the liquor were cold. And this might well be expected; hot water being much fitter than cold, suddenly to pervade the body of the lime, and hastily dissolve, and set at liberty the fiery and saline parts, wherewith it abounds. And what a greater interest salts may have in producing such heats than cold, I have also tried, by pouring acid spirits, and, particularly, spirit of salt, upon good quick-lime. For by this means, there would be a far greater degree of heat excited, than if I had used common water; and this, whether I employed the spirit cold or hot§."

"It is not easy, says the same author, to apprehend how such light and minute bodies should be so long detained, as must by this hypothesis be allowed, in quick-lime especially; since no great heat ensues the pouring of water upon minium, or crocus martis per se, though they have been calcined by a violent fire; the effluvia whereof seem to adhere to them, by the increase of weight the lead and iron manifestly receive from the operation of it**."

* Mem. de l'Acad. an. 1709.

† Boyle Mech. Orig. of Heat, &c.

** Boyle Mech. Orig. of Heat.

‡ Boyle Mech. Orig. of Heat, &c.

§ Boyle Hist. of Cold.

face to oppose to the air, and therefore will undergo less resistance from it. May not this be one of the causes of the spheroidal figure of the earth; and which makes cold prevail at the poles, and heat at the equator in a certain proportion?

Density from cold.

45. Cold also consolidates all those called firm bodies, that is, brings that part, which we call body in them, into less compass than before, and thus unites the matter thereof more closely together: by which means the cohesion of the whole mass is usually increased; which makes what we call strength, or firmness in bodies. It also makes the several parts, whereof the body consists, cohere more strongly to each other; so as not to be so easy to be torn or separated from the adjoining one, as before; which is another cause of the stability found in bodies. Lastly, so far as we can perceive, it binds the very atoms of the body closer, as well as the whole bulk; which was just now said to be acting upon the very substance itself; by which means arises the highest firmness and stability of all things. But what can the most penetrating mind conceive of such last corpuscles? for my part, all I can conceive is, that tho' we go on dividing and abstracting to infinity, body will still consist of other lesser ones; which, if it be a simple body, will be perfectly like the greater; and those again consist of other similar lesser ones. It appears, therefore, that the Creator has infused a principle in things, whereby certain corpuscles unite into little masses, so firmly cohering as that no power implanted in nature, or to be excited by art, can divide them into lesser parcels; and consequently they must remain the same, what violence soever be applied. In the mean while, these may cohere again with the like bodies, and this with so much force, as to form a durable coalition, and rarely to be separated, yet liable to be so by a few certain means; but so as after separating into the above-mention'd atoms, they must thenceforward remain immutable. An intense meditation on the powers and actions of nature led me to the discovery of these simple principles, from whence the atoms of *Democritus*, the *Monades* of some other philosophers, the *Hylarchies* of others, and the ultimate principles of things of almost all philosophers, may easily be explain'd; but it may be asked, are these particles so solid as not to admit fire between them; and are they neither dilatable nor compressible by any power; and does all condensation and rarification then go only to the compounds of these atoms, and not to the component elements themselves? 'Tis a known observation of naturalists and physicians, that all the solid bodies in the three kingdoms are strengthen'd by cold.

The reciprocations of heat and cold.

46. And the alternate change of heat and cold, which prevails in the universe, seems to produce a continual agitation in all the bodies, and the whole universe, and even all the particles thereof, whensoever these two succeed each other; since the action of each necessarily produces the abovemention'd effects.

Useful in nature.

47. But the same degree of either does not long continue, but rather is continually changing, and the succession of one usually tempers the excess of the other, by producing direct contrary effects to the other. Thus, if we attend to the order of nature, she appears to observe nothing with more caution than

than that heat and cold do not long continue the same. This she seems to have had in view, in so ordering the exposition of the earth to the sun's rays, as that the earth might at one time be struck with more oblique rays, and at another with more direct and perpendicular ones; and should not ever remain, even for the shortest space of time, in the same aspect: by which means the different seasons of the year, by the diversities they make in the fire, are continually exciting different effects. I say nothing of the changes of day and night, which are producing continual diversities: so that the same degree of fire continues not a quarter of an hour, even on account of these: and meteors make this mutability still more conspicuous. The sun's heat has scarce scorched the earth, and fill'd the atmosphere with vapours and exhalations, before clouds arise, also thunder, lightning, hail, and rain, which produces a quick change to intense cold. From all which we may infer, that there is a perpetual peristaltic or oscillatory motion of the constituent parts of all the solid bodies in the universe.

48. The excellency of this continual vicissitude consists in this, that hereby other, and much greater varieties of things are produced, than could be if either of 'em were to continue a longer time in the same uniform degree. Thus, the fire, when it continues long, dries and renders what remains of plants and animals durable, and a constant frost does the like: but when it freezes and thaws by frequent turns, all things become intimately dissolved, volatiliz'd and dispersed into air. It would be endless to recount the numerous effects which depend on this principle.

49. Accordingly, the wise author of nature seems so have establish'd this uniform vicissitude in things, that the whole universe might continue in perpetual motion, not only as to the larger bodies, but their intimate and remotest particles; and by such means the rise, growth, state, decrease, and destruction of all things, may be affected by the same law in each.

And continually agitate bodies, internally.

50. But who can define the limits of cold? Where is it so intense as that it may not be still increased? 'Tis probable, this may obtain where there is no fire; but it is impossible to find any such place; nor can we by any art drive all the cold out of any given body or space: it is vain even to think on it. But is the highest degree of cold then more easy to be assigned? By no means; nor do we in the least know how much fire might be collected in a certain space. We are surprized at the force of fire when collected into a focus by concave *speculums*, or refracted and united by convex glasses; but who knows how immensely these might still be increased; if the *speculums* were much bigger, and made of a conoidal, or parabolical figure; or of a perfectly solid, or compact matter, not admitting the least vacuity; or of a body of such a nature, as has a power of reflecting the rays such as they were before the incidence?

51. However, it may suffice for us to denote the degrees of fire, such as they are found among the bodies we converse with. It will be easy like-
No fix'd limits of cold; but comparative.
wise to observe the augmentations, diminutions, and general action of fire, by what we have already shewn. In order to this, we need only observe the increase or decrease of bodies, as to extension; which may be done by proper instruments.

And assign-
able.

52. In the mean while, it will be a matter of great nicety, as well as labour, to determine the quantity of fire in any given place, as that its proportion to the fire of any other known place may be assigned in numbers: to find whether or no it be increased is easy and obvious; but to estimate the precise degree of such augmentation is exceedingly difficult: yet it will appear in the sequel, that this difficulty is by no means insuperable by human industry. — These are the chief particulars clearly deducible from the first and second observation; and which are of much use in chemistry.

EXPERIMENT III.

Drebel's
air-thermo-
meter.

53. Common air, by a small increase of fire, expands every way in its whole bulk as well as in all its parts.

45. This has long been known to philosophers, but farther illustrated and proved by Mr. Boyle; so that we need dwell no longer on it. This was shewn by the thermometer, first invented by *Corn. Drebbel* of *Alcmaer*, which visibly attracts or repels liquors, by the sole means of rarified or condensed air. You may observe how by bare blowing on the ball of this instrument, I make the tinged liquor contained in the tube sensibly ascend; and when I desist from blowing, you immediately perceive the liquor return to its former height.

Improved.

See Plate II.
Fig. 2.

55. The same may also be shewn by applying a warm hand to the ball. — And the like instruments may also be so made, as to note even the minutest difference in the fire, so as to exhibit to the eye a perpetual intermitting systole and diastole of the air: Provide, for instance, a vessel made of thin and very transparent glass, and of a figure compos'd of two spherical segments connected together; so as the greatest opposite segments AB, CD, be not far apart from each other; the bigger and closer this vessel is provided the air may easily be let in and out of it, the fitter it will be for the present purpose. This vessel is to terminate in a slender tube EF, open at F, of a very narrow bore, yet wide enough to admit the air, with its whole force, freely thro' it. This vessel being exposed to the air so as to fill itself therewith, and then plunged with its orifice F, into a vessel full of deeply tinged water; and lastly, the vessel itself ABCD, a little heated, bubbles of air will immediately issue out of EF, through the orifice F, and this so long as the fire remains about the vessel. After enough of this air has been evacuated, viz. a few bubbles, remove the heat, and the tinged liquor will immediately ascend. If then care have been taken, that too much air be not expell'd by the heat, the tinged liquor will be suspended about the middle of the tube FE, where it will play up and down, upon the least variation of heat and cold; and this the more evidently, by how much the glass is thinner, the vessel ABCD, bigger in respect of the tube FE, and the segments AB, CB, nearer: all which is easily demonstrated on the principles of hydraulics. 'Tis obvious why I prefer segments in this instrument AB, CD, to an entire sphere, and why I require them so near together; you are aware, that by this means heat and cold may be the more readily communicated through a large surface, to a small quantity of air, and each part of it.

To represent all this more sensibly, I take a chemical phial, of a large belly and narrow neck, full of air, such as that of the place wherein we are. This I invert in water, and upon applying fire to it, the air-bubbles fly out of the neck through the water; by this it is plain that less of the air remains in the vessel, viz. in proportion to the quantity of bubbles discharg'd; then removing the fire, the water immediately rises into the neck; and bringing the fire to it again, and again withdrawing it by turns, the water rises and falls in the neck by turns, scarce resting a moment in the same place.

COROLLARY I.

56. This expansion of the air, produced by fire, goes to an immense degree, which is not easy to be determined by experiments: for we find that hollow glass spheres exposed in a glass-house furnace, so as to be ready to melt, and then sealed hermetically, and at last gradually cool'd again, are not even thus left entirely destitute of air; since upon breaking the hollow end of a sphere of this kind under water, though the water rush in with great force, there always remains a space in the upper part full of air, which sustains the whole weight of the incumbent atmosphere. This abundantly proves, that the vehement heat of the furnace had indeed rarified the air excessively, but had by no means expell'd it entirely. 'Tis probable a still stronger fire would rarify the air yet further; but it is no less propable, that this rarification would never reach its utmost bounds; so that there always remains some air, even in the greatest fire. In the mean while, M. Amontons has inferred with great sagacity, that the heat of boiling water rarifies air one third part beyond its former bulk. It may perhaps be alledged, that the air collected in the top of the glass sphere, in the former experiment, had been imbibed out of the water, while pressed by the atmospherical weight on the neck of the vessel: in effect, by means of the slowness wherewith the vessel fills, a part of the water which first enter'd, is in a vacuum greater then that of an exhausted receiver, while the cavity of the sphere continues filling; in consequence whereof, part of the air intermix'd with the water must extricate itself, rush into the vacuum, and there collecting, hinder the entire repletion of the vessel. — But on the other hand, let it be considered that all the air which thus disengages itself, and enters the vacuum, returns in a few hours, and is again absorbed within the water, upon which the whole cavity of the sphere becomes full of water alone; as has been well observed by Mariotte, and as I shall hereafter shew in the history of air. Since, therefore, in the present case, the sphere does not fill, 'tis evident that the space not possessed by water, contains a quantity of true air, which the fire, however forcible, was not able to expel, but only to dilate.

Fire expands, but does not totally expel air.

COROLLARY II.

57. Let it now be remember'd, how very small the expansion of iron was found, even in a fire strong enough to make it red-hot; and on the contrary, how great the expansion of air is, even by a slender heat. There

The different expansion of air and iron.

was a dilatation immediately found in iron by a small fire, but it was trifling, and only discoverable by means of an instrument: but what a difference arises in the rarification produced by the same small degree of fire? No body is more easily affected by a slight fire than air, nor any body more difficultly fusible, or expandible to its greatest bulk by fire than iron.

COROLLARY III.

*A considerable
expansion by a
small heat.*

58. Hence we have an opportunity of exhibiting an agreeable and useful phenomenon; viz. to make any assignable increase of heat in the air to a given standard; in order to which the magnitude of the spherical segments in the above-mention'd instrument must be increased, and the tube be longer, and its bore narrower; by which means the smallest difference of heat will have a great and sensible effect in the tube.

COROLLARY IV.

*The natural
quantity of
heat in the
air.*

59. But since the greatest natural degree of heat in the air is found in the scorching dog-days, and a sultry sky rarely reaches the ninetieth degree in Mr. *Fahrenheit's* thermometer; it appears that the degree of such heat has known limits, which it scarce ever passes: so that all its natural variations are still terminated within a declination below that degree: whence *Drebbel's* thermometers become not only handy, but useful. But observe that the augmentations of the weight of the atmosphere, must be remarked at the same time by the barometer; by such means, with very small trouble, we may find out the minutest changes of a small heat.

COROLLARY V.

*The air al-
ways in mo-
tion.*

60. If then we recollect how easily air is dilatable and contractable by the smallest increase or decrease of fire, and at the same time consider the perpetual vicissitude thereof; it will seem to follow, that this air can never be at rest, but must always be moving in all its parts; so that even its last particles must be incessantly vibrating: and this will equally hold in that called open air, which is only confined by the weight of the incumbent atmosphere, as in that shut up in close vessels.

EXPERIMENT IV.

*Decrease of
heat contracts
air, indefi-
nitely.*

61. The smallest decrease of heat contracts air, on all sides, in its whole bulk, as well as in its several parts.

62. This every where appears by the instances which were given in the third experiment; since upon the fire's receding, the contraction was always proportionably observed.

COROLLARY I.

63. This contraction reduces it still into less and less spaces, so long as the fire decreases; consequently it appears impossible to define the ultimate pitch,

pitch, or minimum of this space; since, as we have already observed, there is no expelling all fire out of air. This is very apparent in *Drebbel's* thermometers, when successively exposed to a gradual increasing cold.

COROLLARY II.

64. The greatest contraction, produced in any body by the strongest cold, is less than the condensation observable in the air, upon the least decrease of heat any way cognizable by our senses; and consequently air on this account likewise is fit for discovering the quantity of fire. *Air fit to discover the quantity of fire.*

COROLLARY III.

65. Again, therefore, any the least diminution of heat, or increase of cold, may be made visible, even in a given measure, by converting the third corollary of the third experiment.

COROLLARY IV.

66. The use therefore of the air-thermometer becomes the more conspicuous and easy, by how much the greatest degree of cold has been more certainly determin'd by experiments of artificial freezings, as well as by observations of the strongest natural cold in winter. *What is the summum frigus, natural and artificial?*

67. In that severe cold of the year 1709, the liquor of *Fahrenbeis's* thermometer in *Iceland* stood at the first number; whereas in the present year, in a morning, in the garden of this university, I have usually found it about the fifth division.

68. But all the artifices hitherto known and tried, have never been able to produce an icy cold in summer-time, without the use of water first frozen, in form either of snow, ice, hail, or hoar-frost, though they have sometimes approached near it. But when the weather growing colder, being to tend towards the freezing point, the water is sufficiently cold for the experiment to succeed. There have been divers very operose experiments tried, for producing the most intense cold within the reach of art.

69. The chemists have long ago observ'd, that some salts, at the very moment of their dissolving in water, produced a greater degree of cold than was in them before the mixing. The chief salt, used for this purpose, is common *sal-ammoniac* well purified. I put four ounces of this, reduced to a fine dry powder, in a clean dry glass-vessel well corked in the night-time, and immersing the vessel with its contained salt, thus secured from any wet, in clear water, exposed to the cold air, that every thing might be equally cold, viz. the *sal-ammoniac*, water, and glass; in the morning I applied *Fahrenbeis's* thermometer in this water, till the cold which it diffused made the liquor stand at the 53d degree above O; then dropping in four ounces of *sal-ammoniac*, equally cold with the water, into twelve ounces of this water, and at the same time stirring and mixing it briskly with a stick, in a cylindric glass vessel, the liquor presently sunk in the thermometer from the 53d to the 25th degree; yet the air at that time was hot to the 51st degree: whence it ap-

pears, that a subtriple quantity of *sal-ammoniac*, dissolv'd in water, increases cold by 28 degrees of that thermometer.

*With regard
to the produc-
tion of ice, and
farther.*

70. After this manner we may always be able to make an artificial frost, while the heat of the weather does not exceed that mark'd the 60th degree in the thermometer. For it has been observed, that at the same point of time, when the temperature of the external air reduces the liquor of the thermometer to the 32d degree, the water being then reduced to the same temperature presently freezes. As the cold therefore grows gradually greater from the 60th degree to the 32d, we may by the same artifice raise an intenser cold than is necessary for the turning water into ice.

71. When water, therefore, is become so cold as to reach the 32d degree, this mixture will produce cold to the 4th degree; but if the artist, having cool'd the water to 28 degrees by the first solution in a large vessel, place another lesser vessel full of water in the same lixivium, and thus by means hereof, when it has attain'd its greatest coolness, reduces the water to the highest cold capable of being given it by the cold of the first lixivium, which remains cold a long time, and then immediately take fresh *sal-ammoniac*, likewise cool'd, in the glass within the same lixivium, and mix it again with the coolest water, he may in a short space of time, even in the hottest weather, produce a cold greater than any that has been known in this country. And after having by such a process produced ice, he may raise the cold still farther, by mixing it with fresh cool'd *sal-ammoniac*, and thus at pleasure produce, in the middle of summer, an intense cold, surpassing that of the severest winter.

*The freezing-
point difficult
to observe.*

72. These things it will be necessary rightly to comprehend, it being very difficult to exhibit to the eye the degree of cold wherein ice begins to form: for heat and cold once given to a body, adhere long to it before they quit it; nay, and by how much bodies are more dense, by so much the longer do they retain their heat, as will be shewn hereafter. When the air, therefore, is in such a state as keeps the thermometer at 32 degrees, water will not freeze; since water, being upwards of 800 times denser than air, remains warm a considerable time from the heat which it had before imbibed, after it has undergone a new impression of cold. If any person, therefore, is curious to know in what degree of coldness water begins to freeze, let him first suspend a thermometer in a free open air on all sides; for I have found that if it be hung against a wall, or the like body, the warmth of such bodies will have an effect on the thermometer. After he has thus carefully noted the degree of warmth of the air by the thermometer, let him expose water to the air, so as the smallest quantity of water may by its extensive surface come in contact with the air; which may be commodiously done by wetting a thin linnen cloth with clear water, and thus hanging it for some time in the air: for in this case the linnen will grow stiff upon the first access of the freezing-cold, and thus shew, that the water is beginning to turn to ice. This I have found by experiment to obtain about the 33d degree; and at such degree will water freeze, unless hindered, either by some neighbouring body, or by the heat itself had before imbibed.

73. Hence we deduce the cause why hoar-frost is found long before ice; being only an icy moisture, diffused over the wide surfaces of thin bodies, as grass, leaves of plants, and other roughnesses of the ground. It has also been long ago observed, that the first approach of the winter's cold is perceiv'd by a hoary whiteness spread on the arches of bridges, while the streets, and the water itself, shew no signs of freezing; it being here obvious, that the arch of a bridge, suspended on all sides in the air, receives the coldness of the ambient air on all quarters. And accordingly the same is found to thaw very early. But other gross bodies, retaining their heat long, only receive the cold of the contiguous air by their extreme surface, the impression whereof is gradually propagated through their substance, to the centre of gravity; so that in every different part thereof there is a different degree of cold, till the body have remain'd long enough, in this coldness of air, for its whole mass to have acquired the same uniform degree; though the exact time when this happens may not be easy to assign.

The instant of freezing indicated by hoar-frost.

74. From all this we infer, that the utmost pitch to which cold is brought by natural means, is at O in the thermometer; and that the utmost to which art may bring it by dissolving salts in cold water, is three or four degrees.

75. But the unwearied diligence of M. *Fahrenheit* has discovered something still further, which would hardly have been credited heretofore; an account whereof, as I received it from the author, I will here gratify the reader with; not doubting but that all who love physical inquiries will give him thanks for it.

76. The hard winter of the year 1729 afforded an opportunity of making experiments for producing degrees of cold; among which it fortunately came in his mind to try what the event would be, if spirit of nitre, made very strong, so as its weight to that of pure water might be as 1409 to 1000, and the heat of each 48 degrees, were poured upon ice. He therefore poured two ounces of such spirit of nitre upon a quantity of ice, ground very small; the effect was, that in a moment's time a degree of cold was produced, which upon immersing the thermometer in the mixture, sunk above four degrees below O. His expectation being raised by so extraordinary an event, he proceeded to make a quicksilver thermometer, easily sensible of the least diversity of heat, and carefully divided into parts visible enough, but so contrived as to have in the cylinder over the ball 76 degrees mark'd below O. Then 7 ounces of the spirit of nitre above-mentioned, reduced to the degree of coldness of the atmosphere, which was then 16 degrees, being poured on some ice finely ground, the thermometer immediately sunk 30 degrees, viz. from 16 degrees above O, to 14 degrees below it: the thermometer being then left at rest, the liquor swimming a-top of the melted ice was poured off, and new spirit of nitre poured on the ice remaining undissolved; upon which the thermometer immediately sunk to 29 degrees below O; which done, for want of spirit of nitre, the experiment could be prosecuted no further at that time.

A surprising production of cold discovered by Fahrenheit.

77. Spirit of sea-salt therefore, cold in 17 degrees, being poured on ice ground small, the thermometer presently sunk to 8 degrees below O; then the melted liquor being poured off, and new spirit of salt poured on, the remaining ice thus cooled, the thermometer sunk 14 degrees $\frac{1}{2}$ beneath O. Having seen thus much, the ingenious author concluded, that so extraordinary an experiment should by all means be prosecuted; and therefore went to work again with the same spirit of nitre; but the atmosphere was now come to the point of thawing, which put him upon thinking on a way of preserving the cold already produced. To this end he procured three vessels made of thin plates of iron of a cylindrical figure, about $6\frac{1}{2}$ inches wide; and in these he put three cylindrical glass vessels $3\frac{1}{2}$ inches wide, so as to leave a space of about $1\frac{1}{2}$ inch vacant between the glass and the iron plate; the bottom of the glass vessel was at a like distance from the bottom of the iron-plate vessel. This space, left between the two vessels was carefully filled with cotton; in order that the cold might be retain'd the longer, and the warmth of the air prevented from too soon interrupting the generated cold. These three vessels being ready, and those of glass filled with powder'd ice, he placed glass tubes in them $\frac{3}{4}$ of an inch wide, and full of spirit of nitre, warm in a degree of 32; pouring off the water which sprung from the ice very carefully. This done, spirit was poured on the ice, when the thermometer sunk no further, and what was liquified thereby instantly pour'd off from the refrigerated ice, and immediately afterwards the spirit of nitre, which in the mean while was equally cool'd in the other vessels, as in this by the affusion of spirit of nitre upon ice; by which means the spirit was always kept extremely cold. Thus pouring the spirit on the refrigerated ice four times, and as often carefully clearing it from the floating fluid, the thermometer was at last found to sink 40 degrees below O; and by this time the spirit of nitre had been so acted on by the cold, that it form'd itself into a kind of sharp slender crystals $\frac{1}{2}$ an inch long, appearing as if frozen, and no longer fluid, so that it could only be got out of the tube by force and shaking it; yet no sooner did the spirit thus thicken'd touch the ice, than it immediately melted, and the ice with it; the mercury at the same time sinking from 37 degrees below 40.

78. If pot-ashes be mixed with powdered ice, a cold may be produced 8 degrees below O.

79. No-body could have imagined any thing like this. Nature never produced a degree of cold beyond O; which in effect is severe enough to kill both animals and vegetables instantly; yet art has brought it 40 degrees further. Now when to 32 degrees, which is the freezing point, we add 40 degrees the heat produced in the air is too vehement to be bore for any time, without frequently refreshing and cooling one's self by turns. Hence we learn, that cold, capable of freezing water, may be increased 72 degrees further. What must become of things if the like temperature were found in any part of the globe? We find then, that strong spirit of nitre may be frozen. We also see mercury so condensed, as to take up less space by almost $\frac{1}{269}$ part of its bulk; and we further know, that this wonderful body, though in so vehement

vehement a degree of cold, and so much condensed, continues equally fluid, movable, and dilatable as before; and we know that the same body, from these 40 degrees below O, to 600 degrees above it, at which it begins to boil, has shrunk 640 parts of its whole bulk 10782, consequently, that its proper weight may be tender'd about $\frac{1}{17}$ specifically heavier or lighter, merely by the degrees of heat and cold already known. All this we learn by experiments; and thus find mercury sensibly brought nearer, by means of cold, to the specific gravity of gold. And who shall determine what further degree of cold may be excited by other latent power, either of nature or art? Who can say what changes would befall solid and fluid bodies, if detain'd in such degree of cold? 'Twill doubtless be worth while, having discovered such a cold, to examine all kinds of bodies in it, for the promoting of natural knowledge. Infinite things might doubtless be discover'd by means of such an invention. In the mean while, let the excellent author have his due praise, who first broke the ice, shew'd the way, and afforded us help for going further.

An incredible change of weight in mercury, by fire.

COROLLARY V.

80. Hence also appears the converse of the fifth corollary from the third experiment; viz. that air scarce rests a single moment, neither when open, nor even inclosed in any vessel.

EXPERIMENT V.

81. Pure spirit of wine expands every way, in its whole bulk, by a small degree of fire.

82. Of this we may have a visible proof, by taking a glass-vessel, capable of holding 1933 parts of this spirit; and terminating in a narrow cylinder carefully made, which contains 96 of the same parts, whereof the lower contains 1933; the cylinder being withal divided into numbers corresponding to those parts. In such an one the spirit was contracted to the first number by a sharp frost, in a very cold place, in the year 1709; but upon applying the warmth of a healthy man to the vessel, it expands to the 96th number in the cylinder, and fills it so far with liquor.

COROLLARY I.

83. In this instrument, therefore, spirit of wine, under the greatest natural cold hitherto known, expands itself by the vital warmth of a human body to the 20th part of its bulk. In the mean while it must be observed, that in this experiment, the inner cavity of the thermometer is supposed to have continued the same; whereas, in reality, this also must have been dilated, conformable to the second corollary of the second experiment.

The expansion of spirit of wine, by the heat of the body.

COROLLARY II.

84. Hence, if the proportion of the capacity of the instrument in the severest cold, to the capacity of the same under a degree of vital warmth, could

Difficulty of ascertaining the rarification of fluids.

The Theory of CHEMISTRY.

be accurately known, we might thence learn the true ratio of the increase of the bulk of liquor, answering to the increase of fire between those two intervals; since the difference of the two capacities would give the degree of the dilatation.

COROLLARY III.

*Fluids heavier
at the Poles
than Equator:
whence the ob-
late spheroidi-
cal figure of
the earth.*

85. If therefore the purest spirit of wine, about the poles of the earth, could be hydrostatically compared with the same between the tropicks, 'tis evident there would be a considerable difference between the specific gravities in those two places. 'Tis certain, that all fluids are heaviest about the poles, and lightest near the equator; which perhaps may be one cause of the flat spheroidical figure of the earth; since the same bulk near the poles, is equivalent in weight to a large bulk at another place, each tending with an equal force to the common centre.

COROLLARY IV.

*And the fail-
ure of baro-
meters.*

86. From these observations we also learn, that such vessels, fill'd with liquids of this kind, are always less full in winter than in summer; since the solid parts of the vessels do not dilate so much by the same degree of fire, as the liquids themselves. This the chemists have often found to their cost; by filling vessels in winter-time, and frosty weather, up to the top with liquors, often of the most precious kind; the force of the summer's heat having either penetrated through the cork, or driven it out, or even burst the vessels. This may teach them never to fill vessels in the severity of the winter so high, but to leave the eighteenth part empty; or otherwise to warm the liquors and the vessel itself, to a degree equal to what may be expected in the middle of summer.

COROLLARY V.

*The great ra-
rification of
alcohol.*

87. If the spirit of wine be further heated, so as to be ready to boil, it will rise to 174 parts in the cylinder; in which case it must be expanded about the eleventh part of the whole; and from what has been observed in the first corollary of this experiment, it must even be expanded more. By the way, it may be noted, what a difference it would make between a person's buying spirit of wine by measure in the coldest time of winter, and the hottest of summer. If we suppose the spirit at 40 degrees below O in the greatest cold, and at 174 above O when it begins to boil; 'tis evident there may be a difference of 214 degrees in 1933 parts; and consequently the liquor be contracted and expanded to $\frac{1}{9}$ part of the whole bulk.

COROLLARY VI.

*Ebullition the
last mark of
rarification.*

88. When the spirit of wine is brought to boil, the extreme part of its surface flies off; and while this is continually doing, the vapour spreads itself in the vacuum above, which by this means grows still denser and denser; so that the further progress of the expansion cannot be easily observed: and
when

when the vessel of the thermometer is open'd above, the rarified vapour immediately exhales; which hinders our learning how far it may then be dilated.

COROLLARY VII.

85. Spirit of wine therefore can scarce ever be absolutely at rest: for whether it have air, or the *Torriceillian* vacuum over the containing vessel, it will always either be dilating and resolving into vapours, or contracting, and thus reducing the vapours into spirit again; unless we can suppose the same degree of heat and cold to remain unchang'd: or if it be contain'd in a vessel open to the air, it cannot even then be at rest, but, as we have already observed of air, must be subject to continual systoles and diastoles, as the heat of the atmosphere is alternately increased and diminished; especially while either of those prevails in its highest degree, which is rarely of long duration. Hence also physicians may learn, what frequent, evident, reciprocal oscillations may be produced in the human body, from the parts of spirit of wine mixed with its juices, and sometimes driven through the arteries, and heated by their attrition, then again freed from pressure in the veins, and by this means cool'd: All which it will be easy to deduce.

Alcohol in perpetual motion with its consequences in physic.

EXPERIMENT VI.

86. The lightest and purest ætherial oil of turpentine expands every way in its bulk upon the smallest increase of heat.

Oil of turpentine dilatable by heat.

87. This may be shewn by a spherical phial, terminating in a long narrow cylinder, the body whereof is filled to the beginning of the neck with the oil above-mention'd; for immersing this body in a vessel full of water of equal coldness with the oil itself, the oil remains at the same height; but placing the vessel with the water and the glass-body over a fire, made in an iron furnace, in proportion as the water, and consequently the oil in the body, grows gradually hotter and hotter, the oil itself rises in the neck of the glass, so as scarce to remain two moments at the same height. That it may be observed to better advantage, the phial may be kept thus till the water boils in the vessel, when the oil will remain at a stand, and rise no higher, nor even fall, though kept a considerable while in the boiling water. And though the fire about the vessel be increased, so as to make the water boil more strongly, the oil will still remain unmov'd in the glass. Nay, even the mercurial thermometer does not here rise in the least; which abundantly confirms the fine discovery of M. *Amontons*, which indeed meets with daily confirmations in all kinds of observations, and all sorts of hot liquors. And here the candour, which I trust will ever accompany me, obliges me to own, that nothing I have met with has given me a greater insight into the nature and properties of fire, and its use in chemistry, than this extraordinary experiment of that illustrious author; which you may consult in the original, in the *Memoirs of the Academy of Sciences*. There he shews, that water heated to a degree of boiling, will not conceive any further heat, how much

A boiling heat the highest that liquors can receive, without compression.

The different
weight of the
atmosphere.

Papin's di-
gestor.

The expansion
of oil mea-
sured.

soever the fire be increased. Yet this excellent discovery may receive a considerable improvement, from what M. *Fahrenheit* has observed, viz. that the heat of the same boiling water is always regularly greater, by how much the weight of the atmosphere is greater which presses on its surface; and again, that the same heat of the boiling water diminishes, as the weight of the incumbent atmosphere grows less. Hence, in marking the degree of heat of boiling water, it will be necessary to note the weight of the atmosphere at the same time, by the barometer; otherwise no certain measure will be express'd. In the mean while it must be allow'd true, that boiling water, while the weight of the atmosphere remains the same, becomes no hotter; whatever increase be made of the fire: with which emendation M. *Amonton's* rule will for ever hold true. If the greatest difference of the weight of the atmosphere be three ounces, the greatest degree of heat in boiling water under those different weights will be eight or nine degrees; from whence the author evidently deduces, that by how much the particles of water are more compress'd to each other upon increasing the incumbent weights, by so much the more fire is required to make them recede from each other; wherein ebullition consists. Hence also he finely concluded, that a thermometer applied in boiling water, would mark, by the degree of heat produced therein, the gravity of the atmosphere at that time; and consequently, that this might be accurately enough found at sea, where the common barometers are too much shaken to be of use, by marking the several degrees of increase of heat on a thermometer; which would not be difficult to effect. Hence also, it may be inferred, that our atmosphere itself is the more heated by the sun's rays, by how much it is the more pressed, that is, the nearer it is to the surface of the earth; and the less, by how much the pressure of the atmosphere is less, that is, the higher we go from the surface of the earth. This is also confirm'd by experiments; which shew that on the tops of the highest mountains most exposed to the sun, and never cover'd with clouds, an intense cold still prevails, so that the snow remains solid, and unmelted by the action of the sun-beams. The like may be further evinced from an easy experiment: under a glass receiver of an air-pump place a phial full of water, warm in 96 degrees, extract the air gradually, and as the atmosphere diminishes, you will find a sensible ebullition rais'd in the water; which will be suppress'd again, as soon as the air is re-admitted into the vessel. Hence again we may note at what degree warm water begins to boil, according to the several degrees of the weight of the atmosphere, mark'd on the gauge of the air-pump. Many extraordinary discoveries might undoubtedly be made on this principle. One considerable thing I cannot forbear mentioning: If water and air be inclos'd in *Papin's* digester, out of which nothing can escape, and thus made to boil, the water will be expanded $\frac{1}{4}$, and the air $\frac{1}{3}$: consequently the water will be press'd, as if it had ten inches more than the common atmosphere upon it; so that boiling water in this engine, will be thirty degrees hotter than ordinary, on this single account; to say nothing of any further increase caused by the motion and attrition of the particles of water and air within one another in the vessel; so that 'tis no wonder such surprizing effects shou'd be produced. If now we would examine by the balance, what the pro-

portion of the oil expanded by boiling water, is to the same oil as it was before, we may proceed thus: the oil filled the glass body up to the top of the neck, when the water, glass, oil, and air, were at 52 degrees of heat by *Fahrenheit's* thermometer; and when the water boil'd, and the oil ceased rising, the degree on the thermometer was 212; at which time the oil had risen in the neck to that mark. If, now, I weigh the vessel thus far fill'd with oil, again reduced to 52 degrees of cold, and then emptied to the body, and again weigh the oil in the body, I shall find the oil expanded to a large part of its bulk. Yet it may be proper to note, that no regard is here had to the space by which the compass of the glass is dilated; which having been intimated above, *Coroll. II. Exper. V.* I shall for the future take no notice of.

88. If it be asked, why I here undertake precisely to define the limits of the heat of boiling water in oil of turpentine, which I did not in the former experiment; my answer is, that spirit of wine boils with a much less fire than water; but as soon as the boiling begins, its expansion can no longer be measur'd. See *Coroll. V. Exper. V.* But oil of turpentine, though much lighter than water, cannot be brought to boil by the greatest heat of boiling water, but remains perfectly at rest in this degree of heat; so that the dilatation may conveniently be mark'd in it.

89. In the mean while we may observe something very extraordinary in the phenomena of boiling liquors. Spirit of wine boils sooner than water in a ratio hereafter to be assign'd; yet water boils much sooner than oil of turpentine. May this be ascribed to an affinity between fire and inflammable oils; or is it rather owing to the greater or less weight of the boiling fluid; or lastly to the greater or less tenacity of the parts, and their cohesion with one another? You will find hereafter a multitude of things alledg'd, in order to solve these queries; by which I believe it will appear, that all the above matters are to be taken into the consideration; and further that the variation of the weight of the atmosphere is here of some consequence (f).

EXPERIMENT VII.

90. Pure rain-water being gradually heated, dilates still further at every increase of fire; and this every way, and in its whole bulk. This may also be shewn in a glass-body, where the dilatation is sufficiently conspicuous, as extending to $\frac{1}{7}$ of its whole bulk: for from the 56th degree of heat to the 212th, it keeps continually ascending; but arriving at that degree, boils, and consequently stops; having now acquired the expansion above-mention'd. *The rarification of boiling water.*

EXPERIMENT VIII.

91. Quicksilver easily dilates by the application of heat. This appears by an elegant thermometer made at my request, by that excellent mechanic *Dan. Gab. Fahrenheit.* The lower cylinder of this thermometer contains 11124 parts of mercury, which in the utmost cold observed in *Iceland*, reach'd to the mark O; from whence the further degrees of heat are computed. *The rarification of quicksilver in boiling water.*

H h 2

(f) See *Newton's Optics, Exper. 7.*

puted upwards. Now if this be immersed in a vessel of water gradually heated, the mercury will be found continually to ascend till the water come to boil; upon which the mercury remains immoveable, having reach'd the number 212, and somewhat more; so that setting aside the dilatation of the glass, it now possesses 11336 spaces, of which in the greatest cold it only possess'd 11124; so that by this difference of heat the bulk is dilated to

$$\frac{1}{52} - \frac{25}{53}$$

COROLLARY I.

The rarification of other liquors.

92. After the same manner a strong lixivium of sea-salt, nitre, and of fix'd alkaline salt, is expanded by heat; and even all liquors that have hitherto been try'd; so that air, spirit of wine, oils, water, saline spirits, lixiviums of salts, oil of vitriol, and mercury are subject to this law.

COROLLARY II.

93. The cause which dilates these bodies penetrates glass, and all other vessels, and thus enters the liquors.

COROLLARY III.

94. The same cause also arises from that universally called heat, or fire.

SCHOLIUM.

The physical mark of fire.

95. Henceforward, therefore, I shall call that unknown thing which has this property of penetrating all solid and fluid bodies, and dilating them so as to take up more space, by the name of fire. In effect, I do not remember any body hitherto known, which has all these conditions except fire alone. On the contrary, fire is never known to be present in any body, but it immediately produced these two effects. Add, that in proportion as it is increased, the expansion of bodies is also increas'd. Now such a criterion suffices, in physical matters, to denote and distinguish particular bodies by: nor are there any other marks but of this kind for that purpose; whatever some fanciful philosophers may imagine. It therefore imports us carefully to denote those properties, which we are able to discover in fire; the first of which seems to be, that it exists always, and every where, as will be clearly shewn by the following experiment.

EXPERIMENT IX.

The first way of producing fire.

96. In the coldest season and place, lay one dense iron-plate upon another, both of them being cold, and press the upper on the lower, by laying a weight thereon; then rubbing the one briskly over the other by reciprocal motions, they will first grow warm, and at length hot; so as in a short time to emit sparks, and at last grow red-hot, as if taken out of a vehement fire.

COROL-

COROLLARY I.

97. This production of fire will hold in every season; nor does it matter, whether the weather be hot or cold, excepting that by how much the bodies are contracted by cold, the greatest heat they will conceive; supposing other circumstances the same.

COROLLARY II.

98. Nor is there any place wherein the same effect will not obtain, either on the tops of the highest mountains, or in the deepest caves; in the warmest or the coldest place; though the heat arises quicker and stronger in dry, and slower and in a less degree in moist places: and the like may also be done in any kind of solid bodies.

COROLLARY III.

99. Accordingly, bodies may be heated by mutual friction in a vacuum itself; as fully appears by accurate experiments of the ingenious Mr. Hawksbee; which have also been happily improv'd by my worthy colleague, J. G. s'Gravesande, who seems to have been form'd for such inquiries, and by whom physical knowledge is every day enlarg'd.

COROLLARY IV.

100. But there is nothing more worthy of notice, than that fire generated after the manner above-mention'd, should penetrate all kinds of bodies, even the densest; warm, expand, burn, melt, make them shine, glitter; and, in fine, perform all the effects known to be produced by true fire. Yet it is here generated without any pabulum, or without any pre-existing fire, whence it might be raised; as in the usual manner, where fire is kindled from fire, and flame from flame. We may therefore safely conclude, that this matter is real fire.

COROLLARY V.

101. It appears also, by constant observation, that by how much the bodies rubb'd on each other are harder and more rigid, the stronger fire they produce by their mutual attrition; so that the same body, as it is softer or harder, generates a very different degree of heat. Iron heated red-hot, so as to be ready to melt, being left to cool slowly in the air, in the middle of summer, becomes very soft and flexible; but if instantly immersed in cold water, its parts, which had been moved and made flexible by the fire, become compress'd by the sudden contraction, and are made to cohere much closer together; by which means the metal becomes extremely hard, rigid, and elastic. It is known also, that iron thus harden'd by cold, becomes fitter for striking fire, than if it had been soften'd. If the hard massive axle-tree of a wind-mill be driven too vehemently round by a tempestuous wind, in its rigid socket, it will emit fire and flame; but by the interposition

tion of lead there is less danger of burning. By nimbly striking a hard piece of steel against a flint, sparks are constantly produced; which would not be the case if the collision were made with soft iron (g). Hence, also,

(g) Sir Isaac Newton, and the English philosophers, account for the fire arising upon such collision, on a different principle. They suppose it produced by putting the sulphurous particles of those two bodies in a vehement vibratory motion; by virtue of which motion they become hot and lucid, *i. e.* affect us with the ideas of heat and light.

Bodies of any kind being violently moved against one another, will grow hot by friction, and this to a considerable degree; which shews, that all bodies have fire in them. For fire may be put in motion, and separated from a body, by such rubbing; but can never be generated that way*.

Quicksilver is allow'd the coldest of all fluids; insomuch that "many, says Mr. Boyle, deny that it will produce any heat by its immediate action on any other body, and particular on gold: but several trials have assured me, that a particular mercury may, by preparation, be enabled suddenly to insinuate itself into the body of gold, whether calcined or crude, and become manifestly hot with it, in less than two or three minutes†."

"That quicksilver contains fire, is evident hence, that if you shake it about in an exhausted glass, it will appear all luminous. But for this experiment, 'tis necessary the mercury be very pure and defecate: if it have no tin mix'd with it, you may purge it with boiling-hot vinegar‡."

"By an almost momentary percussion, with no great force, the parts even of a vegetable may not be only intensely heated, but brought to actual fire; as we have tried by striking a good cane with a steel, or the back of a knife; for upon this collision, it would yield sparks like flint. So likewise by scraping a good loaf of sugar, with a knife, numerous sparks will be produced; but upon the collision of a flint and steel, not only fire, but even vitrification, which the chemists esteem the ultimate action of fire, is instantaneously produced: for the sparks which here fly off, are usually real and permanent parcels of stones, vitrified by the vehemence of the motion. And that this vitrification may be of the stone itself, though steel is of a far more fusible nature, I am induced to think, because flints will,

by collision, strike fire with one another. The like also may be done with rock-crystal, and even with diamonds, on the mill whereby they are cut; though fire is not allow'd to fuse them||."

A large glass tube, rubb'd on a linen or woollen cloth, will emit light in the dark; and the tube thus heated, acquires a sensible electricity**.

A globe of glass eight or ten inches in diameter, being put in a frame where it may be swiftly turn'd about its axis; will, in turning, shine, where it rubs against the palm of the hand applied to it: And if, at the same time a piece of white paper, or white cloth, or the end of one's finger be held at the distance of about a quarter of an inch from that part of the glass where it is most in motion; the electric vapour excited by the friction of the glass against the hand, in striking against the paper, cloth, or finger, will be put into such agitation, as to emit light, and make the white paper, cloth, or finger, appear lucid like a glow-worm; and in rushing out of the glass, will sometimes push against the finger, so as to be felt ††.

We must add, however, that the globe is to be first exhausted of air; in which case, both the inner and outer surface will appear all luminous: if it be not exhausted, there will no light be seen in the body itself, but on bodies at a small distance from it.

Hence, and from some other experiments of the like kind, † Graves and infers, that the glass has a kind of atmosphere in and about its surface, which is excited, and put into a vibratory motion by the friction; by which motion the fire contain'd in the glass is expell'd; and that this atmosphere, and fire, are more easily put in motion, and discover themselves more readily, upon the absence of the air ‡‡.

Mr. Boyle furnishes various instances of the effect of friction in the production of heat: Having caused a piece of iron to be turn'd, and placing my naked hand at a convenient distance, to receive the little fragments, as they flew off from the rod; they were so intensely heated, by the quick action of the tool upon them, that they seemed almost like so many sparks of fire. And an expert workman in brass assur'd me, that the heat in the little fragments thrown off,

when

* † Graves and Physic. Element.

† † Graves and ibid.

** † Graves and Element. Phys. Math.

† Boyle Mech. Prod. of Heat.

|| Boyle Effects of Languid Mot.

†† Newton ubi supra.

‡‡ Ibid.

we find that if any soft body be put between two hard ones, the strongest attrition will scarce produce fire; but as soon as such soft body is worn out,

“when he turn'd that metal, were sometimes very offensive to his eyes; and that, when he employ'd a rough tool, which took off greater chips, he had found the heat so vehement, as not only to scorch his eye-lids, but the hard skin of his hand*.”

Of the mechanical production of heat.

Many philosophers have asserted, “That heat is mechanically producible, which appears probable from a consideration of its nature; which seems principally to consist in that mechanical property of matter called motion; but which is here subject to three conditions, or modifications.

“First, the agitation of the parts of the body must be *vehement*; for this distinguishes the bodies said to be hot, from those which are barely fluid: thus the particles of water, in its natural state, move so calmly, that we do not feel it at all warm, tho' it could not be a liquor unless they were in a restless motion; but when water comes to be actually hot, the motion manifestly and proportionably appears vehement, since it does not only strike our organs of feeling briskly, but ordinarily produces numerous very small bubbles, melts coagulated oil cast upon it, and affords vapours, which by their agitation ascend into the air. And if the degree of heat be such as to make the water boil, then the agitation becomes more manifest, by the confused motions, waves, noise, bubbles, and other obvious effects excited therein. Thus in a heated iron, the vehement agitation of parts may be easily infer'd from the motion, and the hissing noise it makes with the drops of water that fall upon it.

“But though the agitation be various as well as vehement, there is yet a third condition required to make a body hot: which is, that the agitated particles, or at least the greatest number of them, be so *minute*, as to be singly *insensible*. Were an heap of sand to be vehemently agitated by a whirlwind, the bulk of the corpuscles would keep their agitation from being properly heat; though by their numerous strokes upon a man's face, and the brisk commotion of the spirits, and their small particles, which may thence ensue, they may perhaps produce that quality.

“The second condition is, that the determination be very various, and tend all manner of ways. This variety of determina-

tions appears to be in hot bodies, both by some of the instances already mention'd, and especially that of flame, which is a body; by the dilatation of metals when melted; and by the operations of heat, exercised by hot bodies upon others, in what posture or situation soever the body to be heated thereby, is applied to them: thus a coal tho' roughly kindled, will appear on all sides red, and melt wax, and kindle brimstone; whether the body be applied to the upper, the lower, or to any other part of it.”

“Hence if we duly attend to this notion of the nature of heat, 'tis easy to discern how it may be mechanically produced several ways; for, except in some few anomalous cases, by whatever means the insensible parts of a body can be put into a very confused and vehement agitation, heat will be introduced into that body. And as there are several agents and operations, by which the heating motion may be excited; so there must be several mechanical ways of producing heat. Various experiments may be reduced to almost each of these heads; chance itself having, in the laboratories of chemists, afforded several phenomena, referable thereto†.”

Consistent with this is the system of the Lord Bacon: that noble author is so far from imagining any particular body necessary to exhibit the phenomena and effects of fire, that he undertakes to assign precisely the mechanical cause of heat, and point out the means necessary to generate it in any body, without supposing any pre-existent fire at all.

From a particular enumeration of the several phenomena and effects of heat, he deduces, (1) That heat is motion: not, that motion generates heat, or heat motion; tho' in many cases, this be true: but that the very thing heat is very motion, and nothing else. But this motion he shews has several peculiar circumstances, which constitute it heat. As, (2) That it is an *expansive motion*, whereby a body endeavours to dilate or stretch into a larger dimension than it had before. (3) That this expansive motion is directed *towards the circumference*; and at the same time *upwards*; which appears hence, that an iron rod being erected in the fire, will burn the hand that holds it, much sooner than if put in laterally. (4) That this expansive motion is not equable, and of the whole, but only of the *smaller particles* of the body; as appears from the alternate trepidation of the particles of

* Boyle Effects of Languid Motion

† Boyle Mechan. Origin of Heat.

so that the surfaces of the two hard ones come to touch, fire immediately arises. So if two iron-plates, smear'd with oil, be rubb'd over each other,

no

of hot liquors, ignited iron, &c. Lastly, that this motion is very rapid.

Hence he defines heat, "an expansive undulatory motion in the minute particles of a body, whereby they tend with some rapidity, towards the circumference; and at the same time incline a little upwards." Hence, again, he adds, that if in any natural body you can excite a motion whereby it shall expand or dilate itself; and can so represent and direct this motion upon itself, as that the dilatation shall not proceed uniformly, but obtain in some parts, and be check'd in others; you will generate heat*.

This system is further supported by Sir J. Newton, who does not conceive fire as any particular species of body, originally endued with such and such properties. "Fire, according to him, is only a body much ignited, *i. e.* heated so hot as to emit light copiously: what else, says he, is a red-hot iron than fire? and what else is a burning coal than red-hot wood? or flame itself than red-hot smoke? 'Tis certain, that flame is only the volatile part of the fuel heated red-hot, *i. e.* so hot as to shine: and hence only such bodies as are volatile, *i. e.* such as emit a copious fume, will flame; nor will they flame any longer than they have fume to burn. In distilling hot spirits, if the head of the still be taken off, the ascending vapours will catch fire from a candle, and turn into flame. So several bodies much heated by motion, attrition, fermentation, or the like, will emit lucid fumes, which, if they be copious enough, and the heat sufficiently great, will be flame; and the reason why fused metals do not flame, is the smallness of their fume; for spelter, which fumes more copiously, does likewise flame. Add, that all flaming bodies, as oil, tallow, wax, wood, pitch, sulphur, &c. by flaming waste, and vanish into burning smoke †.

"And do not all fix'd bodies, when heated beyond a certain degree, emit light, and shine; and is not this emission perform'd by the vibrating motion of their parts? and do not all bodies which abound with terrestrial and sulphurous parts, emit light as often as those parts are sufficiently agitated, whether that agitation be made by external fire, or by friction, or percussion, or putre-

faction, or any other cause? Thus sea-water in a storm, quicksilver agitated in *vacuo*, the back of a cat, or neck of a horse obliquely rubb'd in a dark place, wood, flesh, and fish while they putrefy, vapours from putrefying waters, usually called *ignis fatui*, stacks of moist hay or corn, glow-worms, amber and diamonds by rubbing, scrapings of steel struck off with a flint, &c. ‡.

"— Are not gross bodies and light convertible into one another; and may not bodies receive much of their activity from the particles of light, which enter their composition? I know of no body less apt to shine than water, and yet water by frequent distillations changes into fix'd earth; which by a sufficient heat may be brought to shine like other bodies ||.

"It seems extravagant to talk of heating cold liquors with ice; but I have easily done it, by taking out of a basin of cold water, wherein several fragments of ice were swimming, one piece or two, which I perceiv'd very well drench'd with the liquor, and suddenly immersing them into a wide-mouth'd glass of strong oil of vitriol: for the menstruum presently mixing with the water which adhered to the ice, produced in it a brisk heat, sometimes with a manifest smoke; and that suddenly dissolving the contiguous parts of the ice, and those the next, the whole ice was soon reduced to water; and the corrosive menstruum being, by two or three shakes, well dispersed through it, the whole mixture would immediately grow so hot, that sometimes the containing phial could not be endured in one's hand.

"Though oil of vitriol be one of the most fiery liquors yet known, and even performs some of the operations of fire itself, and thaws ice sooner than the spirit of wine, or any other liquor; yet having put a pound of fine rectified oil of vitriol into a strong glass phial, proportionable to it, we found that, except a little which was fluid at the top, it was all congeal'd or coagulated into a mass like ice, though the glass stood in a laboratory, where a fire was constantly kept not far from it, and where oil of vitriol very seldom, or never, has before, or since, been observed to congeal so much as in part **."

* *De Forma Calidi.*† *Optics.*‡ *Ibid.*|| *Ibid.*** *Boyle Mech. Prod. of Heat.*

no considerable heat will be raised; but after the sides of the hard iron come to move briskly on each other, an intense heat is presently occasion'd.

102. If the bodies rubb'd together agree in other respects, that will always be readiest to yield fire, which consists of the densest matter; and that the most backward which is the rarest; a property which holds universally in the generation of fire. But all circumstances corresponding, a denser and softer body, such as lead, will not yield more fire by attrition than a lighter, but more rigid one, as iron: supposing the two equally rigid, the heaviest will prevail. Hence it appears, why the *Indian Sideroxylon*, a wood most remarkable for its hardness and weight, not only serves them for weapons, but for the kindling a fire, by rubbing two pieces strongly against each other. Add, that fire will be raised the sooner by attrition, by how much the bodies rubb'd are harder and more weighty: thus the collision of flint and steel yields fire in a moment; whereas in lighter and soft bodies this requires some time.

COROLLARY VI.

104. But the chief condition necessary to the producing fire by attrition is, that the bodies, which are rubb'd on each other to this end, be strongly press'd against each other at the time of the attrition. For if an iron-plate be laid on another, so as only to press it with its own weight, and in this case the upper be mov'd, or worked on the under with a certain reciprocal motion, some heat, though only in a small degree, will be produced in each: but if ten pound weight be laid on the upper plate, and it be thus work'd with an equal motion as before, a much greater heat will immediately be perceiv'd; and by thus increasing the weights, the heats produced will still remain the same; so that at length, fire may be produced by an instantaneous motion or stroke, provided the two bodies be press'd strongly, and mov'd swiftly on each other. Something of the like kind, we have already observed, obtains even in the particles of fluids. *The second cause.*

COROLLARY VII.

105. Lastly, it is to be observed, that this fire, from attrition, is so much the greater, as well as sooner produced, by how much, all other circumstances being supposed equal, the motion of the hard particles is the swifter; so that a very slow motion scarce generates any heat, while a quicker immediately produces a very intense one. Grasp a rope close in your hand, and at the same time draw it slowly along, and no heat will be perceiv'd; but as soon as the hand is made to pass rapidly along it, a burning heat will be felt. So a knife, however vigorously press'd on a threshold, or a grindstone, will scarce grow warm; but if nimbly agitated backwards and forwards along the same, produces a vehement heat; so that if applied on a grindstone briskly driven round, it may be made red-hot, provided it be strongly held down, and yet the grindstone all the while will scarce grow warm; because

the part in contact is continually getting from under the knife. Hence, therefore, as the celerity is increased, the degree of fire will also be proportionably increased, and this *in infinitum*.

COROLLARY VIII.

*The three
causes of fire
by friction
united.*

106. From the whole it follows, that wherever the three above-mention'd causes concur, the intensest fire may immediately be produced from the coldest bodies. For if two large massive orbs of hard iron be press'd together by a weight of a million pound, and swiftly agitated by a powerful mover over the surfaces of each other, a furious heat will instantly be produced in either orb. This is evident in wind-mills, when a dry axis is vehemently driven by a whirlwind on a dry socket, which will immediately raise fire and flame; whereas the motion here can be but slow by reason of the small diameter of the axis. The small shavings of iron struck off by a turner will burn the hand; and dust of wood will do the same. May we not therefore suppose, that towards the centre of the earth, where the subjacent bodies are press'd with a vast load of superincumbent ones, so that of necessity they must become extremely dense, a most vehement fire must be produced by so extraordinary an attrition? And must not such fire be continually and gradually increasing (i)? By all this it appears, that we can never define the last and highest degree of fire capable of being produced by attrition; for though it were possible to assign which was the heaviest, and the hardest body, yet there is no ascertaining the utmost weight; nor can we assign any highest degree of motion: consequently there can be no such heat, but that a greater may be raised.

*Leaves its
highest degree
undetermined.*

EXPERIMENT X.

*The interposi-
tion of fluids
hinders this
production of
fire.*

107. But if in the preceding experiment some liquid be continually interposed between the surfaces of the two compress'd moving bodies, no considerable heat will arise, comparable to what would have been, if such compression had been wanting. Of this we have instances enough every where. It may suffice to mention that of the grindstone, on which if the blade of a knife be applied when dry, it presently grows warm, creaks, and frequently emits sparks; but if a drop of water, oil, or spirit, be put between, nothing of this will ordinarily be observ'd. 'Tis known, that the axes of wheels, if smear'd with oil, will scarce grow hot; but if dry, and made to turn in a dry socket, they presently creak, smother, grow hot, and at last catch fire. Who has not heard, as we have already mention'd, that wind-mills have sometimes been set on fire, and burnt down from the like cause, viz. the want of due greasing? But there is no instance where this appears more manifestly than in grinding of glass; where neither the dish, nor the lens to be ground, grow hot, unless the watery, or unctuous medium made use

(i) See Boyle of Cosmical Qualities.

use of be consumed, and the dish and glass left dry; when a violent heat is immediately produced.

COROLLARY I.

108. Hence, by how much bodies are softer, more yielding, less elastic, and rarer, by so much the less are they disposed to produce heat by friction, in comparison of others; and as fluids are generally possess'd of those properties, they hereby become least disposed of all others for producing heat by attrition; instead whereof they yield, shrink back, and fly away: all which regularly obtain in all cases.

*Soft lights
fluids indis-
posed to gene-
rate heat by
friction.*

COROLLARY II.

109. So much the less heat is produced by the mutual friction of bodies, by how much they are press'd together by a smaller force; which also obtains regularly in every case.

*And bodies not
much pressed.*

COROLLARY III.

110. Such also as are agitated by a slight motion, though they have all the other properties necessary for generating fire by friction, will yet afford none; and if they be left at rest, will return to the temperature of the ambient air. This we learn from vast heaps of iron, which how hard soever, and press'd by so great an incumbent load, yet become no hotter than the soft thin light air which surrounds it.

Or at rest.

COROLLARY IV.

111. From all which we may infer, that fire shews itself least by its effects, first, in such places which are either possessed by none, or at least by very rare bodies, and those divided into parts scarce cohering with each other. Secondly, where there is no external cause to compress them together. Thirdly, if there be no cause which gives them motion; such with us would be a *Torricellian* vacuum: for if a glass tube, forty inches long, closed at one end, and perfectly clean, be quite filled with pure well-dried hot mercury, and thus properly immersed by the open end into a basin of the like mercury, and now raised perpendicularly, so that there be nothing but pure mercury in the tube, the descending mercury will leave an empty space in the top of the tube, where there will not remain the least sign of any heavy resisting body: nay, if the mercury in the vessel be duly pressed it will rise again, and replenish the vacant space of the tube, filling it perfectly as before. Here, therefore, appears a space, wherein no attrition of any bodies is found; and consequently here must be the least degree of fire produced by the attrition above-mention'd; and yet upon shaking this tube, a light is produced in this vacuum, as has been elegantly shewn by that great mathematician *Bernoulli*. From whence also some will infer that here also are bodies. 'Tis certain indeed, that what penetrates glass, and quicksilver, and air,

*The natural
absence of such
fire.*

*Pure fire per-
se hardly to be
found.*

must necessarily be found equally distributed in such place ; but it does not any way appear that this, whatever it be, afford the least indication of any heat produced : so that the light here generated by the shaking, may probably be of that kind, which we have already spoke of in the history of light, as a property of fire. Hence we apprehend that light, and perhaps fire itself, can scarce appear to us under the form of fire, without the concurrent action of some solid bodies ; but can freely pass through all spaces without betraying any of the usual effects. In reality, it appears, that the further we ascend from the common surface of the earth as upon high mountains, where there are no meteors to hinder or disturb the equal action of the sun's rays, which all strike directly, and with their full fore, on the opposite bodies, here no heat is perceiv'd, but all things seem extremely cold. In fine, as we ascend nearer to the sun, and further from the earth, where vapours and exhalations are scarce found to mount in any sensible degree, yet there water, if any rise so high, turns to snow, and even remains so on the tops of mountains in the middle of summer : so that it seems as if where there is no hard corporeal matter to resist fire, and where there is nothing capable of exciting an attrition, there fire, though it is present, is found latent and inactive. Consequently as the highest mountains are scarce $\frac{1}{859}$ semi-diameters of the earth high, and yet the cold increases so considerably at so small a distance from the centre of the earth, and upon so small an approach towards the meridian sun, and where the gravity of the atmosphere is still found so considerable, what shall we think would be found if we could make observations a thousand times higher ; or if any relation thereof could be sent to us ?

The alchemical and ancient Jewish notion of fire.

112. So far as we, who know but little of nature, are able to conjecture, all motions appear to decrease the more, by how much we ascend higher from the earth ; so that the uppermost places enjoy a perpetual quietude and silence. Hence the same trees, produced from the same seed, and planted on the same mountain, with the same aspect towards the sun, are always found biggest at the foot, and smaller and drier the higher we advance towards the top. I have sometimes wonder'd upon reading what the ancient alchemists relate, *viz.* that in pure fire there is the utmost silence and absolute rest, and even that God resides therein ; from whence he sends out his ministring fires to move and vivify bodies, which otherwise would die by their inactivity ; thus performing the orders of the Almighty Maker. To the like effect we find testimonies among the ancient Jews and sacred writers (k).

C O R O L L A R Y V.

Violent heat suddenly produced, by the friction of metal against light fluids.

113. Lastly, the sudden and wonderful production of heat and fire, in the coldest, hardest, and heaviest bodies, by mere force of violent friction against the lightest, softest, and coldest fluids, is daily shewn before our eyes. --- Suppose a large solid iron ball shot, in the winter time, from a cannon charg'd with gunpowder, it will fly 600 feet in a minute through the cold air, which makes a greater resistance to its motion than any wind, the most rapid of which

(k) *Exod.* c. 3. v. 2, 3, 4. *C.* 19. v. 16. 18. *C.* 24. v. 17. *Levit.* c. 10. v. 2. *Psalms* c. 104. v. 2, 4. *Hebrews* c. 1. v. 7. and c. 12. v. 29.

which only moves $22 \frac{1}{4}$ feet; whilst at the same time it condenses the air with so much violence, as to throw down every thing, tear up trees, break their branches, and beat buildings, &c. to the ground (1). Hence it appears, how much friction the ball must have undergone in its passage, which, by the way, did not proceed in a right line, but by its whirling motion continually describes a cycloid with every point of its body. When it falls it is found quite hot; notwithstanding that, in its whole passage, it had continually met with new cold air, and consequently must have lost every moment some part of the heat it had acquired. This heat of the ball could not have arisen from the flaming gunpowder, whereby it was exploded, since it only remain'd in that flame an incredibly small space of time, hardly the $\frac{1}{1000000}$ part of an hour, in which time it is by no means credible so solid a ball should have acquired such a heat; which is much more naturally accounted for from the great attrition of the ball, driven with such a velocity against the air, and repell'd by a wind, which is $27 \frac{3}{11}$ times swifter than the strongest wind hitherto observed.

114. It appearing then, by all kinds of experiments, that fire may be immediately produced by the friction of any kind of body, at all times in every degree of cold, and every place, where trial has hitherto been made, provided the three physical conditions above-mention'd be found; we may hence infer several things which will give an insight into the nature of fire. *The doctrine afforded by the premises.*

115. And first, that fire, as hitherto known, is present in all places, tho' not always discoverable by us, when we look for it in the vulgar manner; for the best thermometer always shews, that in the highest degree of cold above-mention'd, there is always some heat remaining, though it be usually mistakenly supposed, that there is no fire left, when the thermometer sinks to O. *Fire present every where.*

116. Nor is fire only contain'd in all space, but found equally distributed in all bodies, the rarest as well as the most solid; for if a very sensible thermometer be applied in the extremity either of summer, or winter, to a glass vessel in which is a *Torricellian* vacuum, where any one would perhaps imagine, that there is more fire contain'd, and at the same time the thermometer be applied to the heaviest of all bodies gold, we find the very same degree of heat and cold in both; provided both of them had continued long enough in the air, without any change therein as to the degree of heat and cold. This I have never found any body could believe at the first relation; but the truth and certainty of it is sufficiently made appear by the following experiments. In a sharp winter's cold I placed a *Torricellian* vacuum, an exhausted receiver, air, pure alcohol, expressed oils, distilled oils, water, lixivi-
And in all bodies.

117. I have not therefore found there is any space in nature destitute of fire; nor have I, with all my endeavours been able to discover any body, endued with such power by the Creator, as to attract this fire, thus equably distributed, *In all space.*

(1) *Mariotte*, p. 140.

distributed, and fix it to itself, so as to have more than its share thereof: in fine, I do not find that there is in nature any such thing as a magnet of fire; but, by all I have been able to observe, it appears, that if either the attrition, or the mixture of bodies come to be at rest, the fire they had conceived become again equably diffused in proportion to the space as before. Nor does it signify, whether such spaces be void, or full of matter, or what kind of bodies it be fill'd with. Here some will be apt to cry out, that I am dealing in chimæras, and alledging things, not only vain and false, but contrary to common sense and experience, which manifestly shews that iron, in winter, is colder than feathers, and quicksilver than alcohol. But let it be considered, I am not here speaking of fire appearing to the senses by its degree of heat and cold, but of fire discover'd by that characteristic above settled, of rarifying bodies: as for that greater degree of heat, discoverable in alcohol, than in quicksilver, or ice, I shall endeavour to account for it, after having treated of the different manner, wherein solid and rare bodies are affected by heat and cold; to do it now would be to trespass against my method. Another thing that may be alledg'd in favour of this doctrine of fire is, that the fire thus equably distributed, by means of rest, through all places, is scarce perceived at all; by reason that things which are every where perfectly the same, and do not distinguish themselves by any diversity in them, usually pass for nothing at all; as would easily appear, if there were at any time such a degree of fire, as should make no change in any fluid or solid body; for no one would then think either of fire, heat, or cold; but as soon as the fire should be so far increased, as to render wax a little softer than before, they would immediately begin to suspect some accession of heat or fire; because they know that wax is liquified by fire. And from this mistaken opinion it arises, that mankind conclude, whenever fire becomes more manifest by its effects, that some new fire is generated either by art or accident.

Fire continually in motion.

118. A third point deducible hence is, that this fire, thus diffused thro' all spaces and bodies, is continually in motion; for who will pretend to assign the last point of absolute cold, that is, the perfect rest of fire? but the smallest beginning of fire, or heat, or rarifying power, immediately begins to expand all bodies, and remove their parts from their natural closeness; and as long as it does thus, hinders the proper cohesion of the elements? all which plainly shews, that there is a real motion exercised in them. And hence it appears probable, that fire is always contained, as well as it is always in motion or action, both *in vacuo*, and in the void spaces of solid bodies, as in so many vessels, and thus continually produces certain operations inseparable from it; all which principally aim at this, *viz.* to remove the elements from one another, and thus make the fire expand itself more equably. In the mean while it is no less certain, that the particles of the matter are continually endeavouring to draw nearer each other; and thus confine the void spaces between them still more and more; and consequently extrude the fire contain'd therein, as much as may be, by destroying the equilibrium. Thus there would be a perpetual action and re-action between the fire in the pores, endeavouring to expand the particles, and the natural endeavours of bodies,

bodies, which tends to make them contract more closely. After this manner, therefore, may all bodies, placed in immense space, be divided into fire, which expands them, and bodies which are continually striving against the separation of their elements: thus the two principles, the one expansive, the other contractile, prevail through all bodies, and become the causes of a multitude of corporeal actions, whose power or energy, therefore, can hardly be conceived from the idea we have hitherto had of them, and is thoroughly known by none but God himself.

119. The more a man considers this, the more certain it appears, that fire cannot penetrate into the last and least elements of bodies, but is repelled therefrom, as often as it attempts it; and this with the more force, by how much it endeavours to penetrate more forcibly. By this means there must arise a kind of attrition betwixt fire and other bodies; and consequently fire is never lodg'd in the proper substance of bodies, but only in the interstices, which are left between the particles, even of the most solid bodies. In effect, the *ἀντιστοιχία* of Democritus, called impenetrability by others, appears so essential to fire, and all other bodies, that in all the experiments which have hitherto been made, it seems inseparable therefrom.

Fire does not penetrate the substance of bodies.

120. We are to consider, that while the fire here described, lodg- ing within the pores of bodies, is not moved, or acted on by any other cause, it does not discover itself by any effect; because it can go out of the pores, as easily as enter, and therefore will make no great alteration in its action on the containing body; since it appears to be present, and act equally every where. To conceive the more readily what I mean, take a very sensible thermometer, and note the degree of heat indicated thereby: then apply it to the mouth of a pair of large bellows, and blowing briskly therewith against the ball of the thermometer, you would naturally expect that this new blast of wind should produce some notable cold, and the thermometer be affected thereby: yet the contrary is found; the instrument standing still at the same time. Hence we learn, that neither heat nor cold are augmented in this manner to any sensible degree; for fire moves almost as easily through quiescent, as through moving air, by reason of the great rarity of it. Yet if the air were agitated with a much greater force than that of the bellows, the degree of heat would be something increased, as above shewn, by the attrition thereof: whence probably it may be, that in furious storms, other circumstances being supposed equal, the heat is rather increas'd than diminish'd. Accordingly, I have formerly observ'd the highest winds to be attended with a hot air; and the severest frosts happen when the wind is still. It may be ask'd then, why does the wind, nay the very breeze, appear cold to our body, especially when warm'd; by which men are induc'd to believe, that it has some cooling power? And is it not known that when a nipping wind blows strongly for a considerable time, the excessive cold thereof becomes offensive to the body, and if long enough continued, occasions a gangrene? The fact may be allow'd; but the cause is very different from what is ordinarily assign'd: it must be remember'd then, first, that no man can live in an are which is

Wind not productive of cold.

But rather of heat.

Tho' it cools the body.

air

90 degrees hot, but that all known animals quickly die therein ; yet the vital warmth of our bodies is 92 degrees, and that of infants often 94, as *Fahrenheit* has observed.

The body hotter than the surrounding air.

121. Hence a man is always hotter than the ambient air ; and thus the garments wore on his body are always warmer than if they were exposed on all sides to the open air ; nay, and this heat of the man warms the air contiguous to his body : if, therefore, the air, without wind, be at rest about a man's body, the atmosphere of the man will be warmer than that of the air, and accordingly, he will feel the air hot as it really is ; but when the wind rises, this warmer air which invested the man is blown away, and its place supplied by fresh colder air ; upon which a sensible cold must be perceived in the lungs, and on the surface of the body : add, that the heat given to the clothes by the warm body is carried off by the same wind, and thus a new fresh coldness is continually imparted by them to the body ; the effect whereof is the same, as if a man should be continually putting on a fresh clothing of cold air : and hence it appears, that wind may cool the body of man by carrying off its excess of heat, though it do not generate cold of itself. This remark being of incredible service in medicine, we will further illustrate it by an example. Suppose a man by exercise, a disease, or any other cause, heated too 100 degrees within his clothes, in a still air ; and suppose the temperature of the air at that time to be 48 degrees ; it will be easy to conceive, that his apparel will be heated thereby almost to the same degree as the body itself ; nay, and the quiescent air about his clothes and his head, will conceive a considerable degree of heat beyond that of 48 degrees. I have often observed upon the approach of a warm man, that a thermometer would be affected to the distance of four feet, by the mere warmth of the effluvia perspiring from his body ; and on his retiring again, the effect would entirely cease. If therefore the neighbouring air and the clothes be supposed hereby reduced to 60 degrees, the body of the man will be as it were immersed on all sides in that temperature, and his vessels and humours relaxed according to that degree, and the cutaneous nerves affected with the sense of such a heat. Suppose this body now exposed to a wind, which scarce moves six feet in a second of time ; the heat then of the ambient air and his clothes will be carried off within this second ; and a lesser degree of heat, *viz.* of 48 degrees be applied on every side to his body : thus will his whole frame become physically 12 degrees colder on the outer parts ; and as the wind is supposed still the same: the body must in a short time shrink into the most shivering cold, as the continual application of cold air, incessantly carries off an equal part of his vital warmth : from all which the truth of the paradox above is fully settled.

The uses hereof in physic.

122. For if, in lieu of the human body, a thermometer be exposed to this wind ; the degree of heat will be the same in the liquor of the thermometer, as in the ambient air ; and hence, whether the same quiescent air remain contiguous to the surface of the thermometer, or whether a fresh parcel be perpetually succeeding, the degree of heat will be the same ; and consequently, even the highest wind will impart no cold to the thermometer, except the air in the mean time acquire some new temperature in the place from

from whence the wind blows. Hence, such as are conversant in medical matters, will easily conceive how it happens, that the healthiest and strongest constitutions are often seized with the most severe diseases, and even sudden death itself, by being exposed to a cold wind, whilst the body remains heated to a degree of sweating by vehement motion; and especially if people, after heating themselves by violent motion in a cold wind, rest again too hastily. Hence arise asthma's, that continue during their lives, quincies, pleurisies, peripneumonies, gouts, and rheumatisms: and for those of a weaker and tenderer frame, we often find them surprizingly affected by the least wind, even the gentlest breeze; and a window that is not close, but lets in a little colder air, than that within the chambers where they live, will have the same effect; especially if they have long accusom'd themselves to direct the warmth according to a thermometer: a thing highly prejudicial to a sound state of health.

123. From hence it will now be easy to determine something concerning the nature of fire; for if two dense hard elastic bodies be struck against each other with great force and velocity, all the parts of such bodies will every moment be closely compressed; and being rigid, will react with equal force. Hence a quick and powerful contraction and expansion will arise in every part, resembling that swift kind of vibration, observed in stretched strings: how great these vibrations are, may be learnt from the instance of a bell, when struck with a single blow, by which the whole bulk, however vast, will for a long time expand, and contract itself in infinite ellipses. And when the attrition above described is produced, with what force and velocity are all the particles of the rubb'd body compressed, shaken, and loosen'd to their very intimate substance? Hence the shrill and intolerable creaking of rubb'd bodies, which is the certain sign of their utmost vibration. We are to suppose, that the whole body thus rubb'd, press'd, and loosen'd, is rapidly moved in all its parts; since all strings vibrate backwards and forwards with the more swiftness, by how much they are more elastic, shorter, and tighter stretch'd: all which conditions here concur. This is sufficiently evident from experiment. Nor is it less clear, that the fire lodged in the pores of bodies, and which there exerts a power of expanding the same in all their dimensions, and which being again strongly repressed by the contractile re-active power of the expanded body, undergoing a strong attrition by the action, is every moment violently compressed and relaxed again in all the pores. Hence, as the same fire appears the most powerful of all elastic bodies, from the consideration of its expansive force, its proper power and motion seems to be exceedingly increased; and hence in bodies under this attrition, and in fire equably distributed through the pores thereof, we may suppose a great degree of motion produced, and long continued: but this cannot be without the neighbouring and ambient air being equally agitated by both the said means; and this the more violently, by how much it is the nearer. Nor can it be otherwise, since it is evident that fire is equably distributed, and perhaps acts equably in all quiescent bodies; and in spaces incapable of all motion and mutation; consequently the adjacent air must every where follow the strokes

*The action of
fire as generated by friction.*

of the fire, intercepted in the pores of the bodies rubbed, and therefore must also be reciprocally driven this way; and that this vibration of the fire must also continue as long as the vibration of the bodies produced by their attrition, or those reciprocal agitations of the fire be reduced to rest, or to a motion equal to that of the other fire in the neighbouring spaces and bodies. But since by the motive causes of the rubb'd bodies, a new motion is added to the fire, besides that common one which it had before, the power of the fire must hereby be increased, which, as it tends to expand bodies, will presently discover itself by this sign; and hence the power of fire may be understood, as excited by friction; and thus at the same time we see the reason of several phaenomena. As,

*Whence the
solution of se-
veral phaeno-
mena.*

124. (1) Why only elastic bodies chiefly generate fire by friction? because these alone vibrate in their elements. (2) Why the most elastic bodies generate the most fire, as a hard flint struck briskly against steel? because the quickest and greatest vibrations arise herefrom. (3) Why the softer and unelastic bodies generate less fire? because they do not rebound, nor return, and restore themselves. (4) Why, notwithstanding, the attrition of lead upon lead begets a vehement heat? because the last elements of bodies are expansive and contractile both of their own nature, and by reason of the fire; though the larger bodies compounded of these elements cohere together in a manner which makes them resist less, and easily give way: whence it appears, that there is one kind of elasticity of the elements, which is common to all bodies, and capable of being changed by heat and cold; and another species, which resists a stroke, and restores itself to the figure it had before the same. (5) Whether fluids do not also generate heat by attrition? If elastic they readily will; if unelastic, with difficulty: thus water is very difficult to heat by friction; yet if unelastic fluids be driven with a vehement force through very narrow channels, they will conceive heat by the attrition, because the last elements of this fluid seem in some measure elastic. But if the tubes be elastic, through which the fluid is driven, a greater heat may be generated: and hence our blood, being elastic, and impelled violently through elastic arteries, becomes warm in a state of health. But the more the constitution of the blood tends to that of water, which is unelastic, so much the less heat is produced in the body: and the like may be observed, in proportion, as the elasticity of the arteries themselves grows less and less. (6) Why the interposition of a fluid between two bodies in friction, impedes, or lessens the degree of heat? because the impress'd motions are eluded by the perpetual slipping backwards and forwards of the fluid. (7) Whether the elastic properties of bodies contribute much to increase the action of fire thereon? which it does in a great degree, as we have just shewn. (8) If the tendency of gravity did not determine bodies to one another, what would become of fire? Its effects, in that case, would be scarce perceivable; as appears from what has been observed of deep mines, and the tops of the highest mountains. (9) What then must we say of the deepest wells, where the air is eternally at rest? there will always remain an equal degree of heat and cold, which will be peculiar to peculiar depths, suitable to the temperature of that in the country adjoining; as has been

been shewn by some elegant experiments made in the well of the royal observatory at *Paris*. (10) Why the striking of flint against steel affords the largest and brightest sparks in the coldest weather? But there would be no end, were I to rehearse all the new considerations which offer themselves on this head. Gravity, elasticity, and fire seem the three capital, and most universal causes of corporeal actions; to which, when attrition is superadded, a multitude of phænomena common to them all may be accounted for.

125. (5) Hence also we may infer, that to produce the greatest degree of fire, we must suppose the heaviest, and at the same time the most elastic of all bodies, placed in the deepest parts of the earth, and strongly compress'd by others laid on them, and lastly, agitated on each other with the swiftest motion, that can be conceived. Hence also it is highly probable, that in receding from the centre of the earth, the intense heat thereof continually decreases, and becomes least in the middle term or space between two planets: supposing our earth and moon of the same nature, in the centre of each of them must be the intensest heat; which will sensibly decrease till it arrives at that place between the two spheroidal orbs, where the power of each terminates (*m*). Hence it appears impossible for birds to fly from the earth to the moon, or from the moon to us; as some philosophers have imagin'd; neither could they subsist in the abyss: and what we have said concerning the sun and moon will equally hold true of the other planets. Hence also it appears probable, that heavy bodies are only found about the planets, and perhaps about the sun or fixed stars; from whence they sensibly grow lighter and rarer, till at length they perhaps grow void of all resistance: and yet fire must be there found in equal quantity; consequently fire may probably not be heavy, but indeterminate to all places; probably it may have no power of itself, except of equally expanding itself every way, without any particular determination to one point more than another: and hence in those very high places, the action of fire may amount to nothing; on ac-

The maximum and minimum of fire.

Why birds cannot fly high in the atmosphere.

K k 2 count

(*m*) *Morinus*, a French author, who had the curiosity to descend himself into the mines of *Hungary*, some of which are 3 or 400 fathom deep, relates, that after he had descended about 100 fathom, he came into a very warm region of the earth, which lasted to the bottom of the mine; being so hot, both in winter and summer, that the labourers usually work without their clothes: he adds, that he himself was scarce able to bear the heat. He was further told by the overseers, that 'twas universal, the lower they descend beyond 100 fathom, the hotter it is still growing.

Mr. Boyle, however, having been to the bottom of some mines himself, suspects, that this degree of heat, observed in the *Hungarian* mines, might in great part proceed from the peculiar nature of the place, or of the minerals generated there; and not wholly from their depth. Very credible eye witnesses have assured him, that in some parts of *England*,

they dig up large quantities of a kind of mineral, supposed to be vitriolic, which, by the bare addition of common water, will grow so hot as almost to take fire: so that the *Hungarian* mines being deep, and not destitute of water, it may be suspected, that either this fluid, or some peculiar mineral spirit, or juice, may with the mineral produce a warm steam, which for want of sufficient vent, in those close places, yields a considerable heat*.

"It cannot be reasonably pretended, that the subterranean heat proceeds from the rays of the sun; since they heat not the earth above six or seven feet deep, even in the southern countries. And if the lower part of the earth were, of its own nature, cold, and received the heat it affords, only from the sun and stars; the deeper men descend therein, the less degree of heat and steams they would meet with†."

* *Boyle Abr.* Vol. III. p. 232.

† *Id. ibid.*

count that dense elastic moving bodies, rubbing against each other, are there wanting. May not the comets probably take their courses thro' those spaces between the planets and stars, where there are the least obstacles, and consequently the easiest passages; the motions and orbits of these wonderful bodies being not yet accurately ascertain'd?

Other circumstances that increase heat by attrition.

125. (6) It also appears, that those bodies which having such large pores, as that air, water, spirits, and oils, may have easy entrance into, and passage from them, are the least disposed for generating heat by attrition: but that those whose corporeal substance is so closely condensed, as that their pores are too small to admit any thing except pure simple fire, will, when rubbed against each other, excite a brisk motion in the fire therein contain'd. If then it be consider'd, that the surfaces of two bodies may so exactly correspond to each other, that, when fitted together, and thus moved, nothing can insinuate between them but pure fire; if these be rapidly turn'd on each other, while in such state, the fire alone between them becomes agitated; and a fervent motion is thus produced. Again, if the bodies be moved on each other so swiftly, as that neither the air, nor any other bodies can follow with equal celerity, excepting the fire alone contain'd in them; 'tis probable that this fire will rush so swiftly into the void places, and those already possess'd reciprocally, as that by this means more fire will be collected about the places adjoining to the surface of the bodies rubb'd than was before; which may be another cause why heat is rais'd by attrition. Lastly, if the particles of any hard body be connected closely together, and at the same time its fibres and laminæ be so disposed, as to be very short and tremulous; they will, by their vibration, agitate the fire very swiftly and strongly, so as by their vehement attrition to raise a considerable heat in a short time: in effect, a great motion is excited in fire by all these means.

Why bodies of different densities heat and cool differently.

126. (7) It remains to be strictly enquired, whether there be any power in bodies themselves, whereby fire is attracted to them in such manner, as that the more solidity the bodies have, the more fire they imbibe. This is never found to obtain in quiescent bodies; but it uniformly appears by all experiments, that there is neither more nor less heat or fire in a *Torricellian* vacuum than in gold, when both of them are left at rest under the same temperature of the air. But whether the solid matter of bodies acquires, by the attrition so often mention'd, any power like to magnetism, whereby they may attract fire, and when brought in contact, retain it along time, is another question, which I have much considered; and find that a body conceives heat from the same fire, so much the sooner by how much it is the rarer; but, when once heated, cools again so much the slower, by how much it is denser; and the more speedily, the rarer it is, from whence we may infer, that there is something in solid matter much like to attraction; and particularly since this law obtains equally in elastic, as in the unelastic bodies (*n*). The fire is very vehement in the focus of a burning-glass, yet

(*n*) "Sir Isaac Newton shews, from a great variety of particular experiments, that bo-

"dies act on light, at a distance; and by
"their action inflect and bend its rays; which
"action,

yet if the glafs be covered with a shade towards the fun's rays, the heat immediately ceases in that place of the air, where a moment before it was so great: but if a metal had been there heated with the same fire, it would have retain'd its heat a long time. If one vessel full of air, and another of water, be expos'd to the same heat, the warm air in the one will perhaps be a thousand times rarer than the warm water in the other; but the water as it acquires heat more slowly, retains it the longer; so that the air will perhaps be cool again in a thousandth part of the time. From the whole we can only conclude, that fire enters and passes out of bodies with the more difficulty, as the bodies expos'd to it are denser; nor does it clearly follow, that there is any thing more in the matter, though if we might be allowed to form a conjecture, 'tis not improbable, but that fire, in entering dense bodies, shakes the particles thereof, and thus causes vibrations, which will be greater according to the degree of expansion, and more durable according to the density; which also, so long as they continue, will agitate the contained fire, in the same manner as attrition has before been observed to do in elastic bodies.—Upon the whole, therefore, we discover nothing like the magnetic power above hinted.

127. It is to be remember'd, that by the doctrine of the first experiment it appeared, that the hardest and most solid bodies, when penetrated by the smallest fire, are continually shaken and kept in motion through all the particles of their whole mass; and consequently the same, when heated after a like manner by attrition, will be moved and agitated after the same manner. Heat from percussion.

128. By such means the particles being all, at the same time, put into a tremulous motion, may be supposed to rub mutually against each other, and thus be moved after the same manner as if rubbed from withoutside; consequently they will also move the fire contained in the body, and attract, collect, and retain it a long time in the solid matter of the body; by which means the filaments of the body will be again acted on, and rubbed in their turn by the fire: on which account also, the fire once conceived, will be continued a considerable time.

129. The great Mr. Boyle long ago shewed by experiment, that a solid piece of cold iron laid on a cold anvil, and plied thick with strokes of the hammer, would by the compression thereof, and the elastic power of the metal, grow hot, so as to kindle sulphur cast on it: and again, that an iron nail, when driven up to the head in hard wood with a cold hammer, when it can no longer penetrate further, immediately grows hot, though the hammer

" action, *ceteris paribus*, is strongest at the
" least distance. He adds, that in passing
" by the edges and sides of bodies, the rays
" bend several times backwards and forwards
" with a motion like that of an eel: and
" that the rays which are either refracted
" or reflected, begin to be bent before they
" arrived at the reflecting or refracting bo-
" dies*.

* Optics.

" As attraction is stronger in small mag-
" nets than great ones, in proportion to their
" bulk; and gravity is greater, on the sur-
" faces of small planets than on those of great
" ones; and small bodies are agitated more
" by electric attraction than great ones: so
" the smallness of the rays of light may con-
" tribute much to the force of the agent where-
" by they are inflected, &c. †."

† *Id. ibid.*

hammer itself continues cold. The same gentleman also shew'd, that iron will grow hot in filing, though the file itself remain cold (o).

By the undulation of elastic bodies.

130. (9) The ninth thing we gather from the preceding observation is, that a great heat may be produced where we are sure nothing else has happen'd; but that a piece of elastic iron, being only compress'd between irons also elastic, and restoring itself every moment in the intervals between the strokes of the hammer, yet a sufficient heat is collected thereby to raise a flame in sulphur, when sprinkled on it.

131. (10) We may suppose, that such elastic body, after it has once been heated by this action, will long retain such excursions and incursions in its compressed and rebounding parts; and thus also continue the motion of fire, after the same manner as a cord, when struck, will continue its tremors, or a bell its sonorous undulations a long time.

Fire not thus generated.

132. (11) A matter of great moment remains to be inquired, *viz.* whether the fire excited here by attrition and percussio, be really generated by such vibration of parts, or existed before: also whether the vibrated parts themselves do by the agitation so attenuate their bulk, as that flying off, they turn into fire itself; and thus other bodies, not igneous, by attrition, percussio, and vibration, commence true fire; so as fire may be made out of what was not fire before. This to me appears impossible; for I have shewn that fire exists every where; that it is equally diffused in all places; and have also proved, that it may be produced in more or less quantity by any attrition of any body; and it appears that fire, however produced, is always the same, and retains the properties peculiar to fire alone: from whence it is by no means conceivable, that such fire should be continually generated, and when generated, remain still the same, and in the same quantity; but that in all those operations the fire is so alter'd and affected by motion, rest, collection, dispersion, and diversity of direction, as that it sometimes appears, and again disappears to our senses.

But only collected and moved.

133. Upon a mature consideration of the several matters hitherto alledged concerning the criterion of fire, and its production, I am fully confirmed in this opinion of its origin. 'Tis easy to conceive, that fire may be moved by the attrition and percussio of a hard elastic body, as also, that by such motion, it may at the same time move others; and it is easy to conceive the motions of a solid body so quick, as that nothing but fire can keep pace with them; which by such means will be collected about it; and that in what manner soever fire is produced in one place, just so much is lost from the adjoining ones. And this migration of fire is as readily conceived, as that of any other fluid; but as soon as it is collected out of a larger space into a lesser one, it must make its appearance to our senses as if but just generated, by reason of its quantity and effects.

Recapitulation.

134. (12) Lastly, let me rehearse some of the things above laid down; *viz.* That in all parts of the world, even where the greatest cold prevails, which nature or art can produce, there is fire present in great quantity; since by attrition and percussio, we can immediately excite an intense fire, as appears by the collision of flint and steel, and the application of a thermometer to

all

all places and bodies under the same temperature: from all which I flatter myself I have explain'd, by experiments, and their corollaries, the first physical manner wherein we may always and every where certainly produce that which penetrates all things, and expands or rarifies all things, except space alone; and that this is what we call fire: having therefore discover'd something concerning its hidden nature, we are sufficiently encouraged to go on with our inquiries.

EXPERIMENT XI.

135. The fire above explain'd, and distinguished by its power of rarifying all bodies, of moving all bodies, and penetrating all bodies, if it be collected in any space or body, so as to be perceivable by our senses, removes itself out of the same by its own power, and expands every way from the centre of its space or body. *The recession of fire spontaneous.*

136. To conceive the meaning, and at the same time the proof of this proposition, immerse a leaden ball in boiling water, till it have acquired the same degree of heat with the water; then draw it out by a thread fasten'd to it, and we shall find it diffuse an equal heat from every point of it, both by the judgment of our sense, and the thermometer, which placed at equal distances from all parts of it will be moved equally: a certain indication of the equable diffusion of the heat or fire. Thus a piece of ignited iron shines equally, and exhibits its fiery colour on every side, at the same time heating us equably, at equal distances from every part: add, that all its other effects of fusion, exsiccation, and burning, are alike produced on every quarter. But what shews this still more incontestably, is, that a thermometer, when immersed in any fluid, immediately, and equally on every side, accommodates itself to the temperature of the fluid, by either rarifying or contracting its substance. And this holds in all instances without exception.

COROLLARY I.

137. It appears, therefore, a property belonging to fire, that its parts endeavour equably to diffuse themselves; that is, by moving every way, and consequently tend neither more or less to one point than another. This, it must be own'd, looks somewhat extraordinary, and scarcely intelligible, as differing very little from the idea which we have of rest. To conceive it the better, suppose a hollow sphere absolutely empty, and in its centre another spherule an hundred times less, the several parts wherof have a power, by equally receding from each other, to fill a greater sphere exactly; here than will be a true motion of all the parts, and yet the whole bulk thus moved, be indifferent to all sides. — From the preceding experiments it appears, that the fire contained in our common air, will be continually expanding and compressing on this account, if there were no other. *The proper conatus of fire.*

COROLLARY II.

138. The state of fire, defined by the preceding corollary, may be called its stagnation; the powers of stagnating fire then will be as the spaces wherein it is contained; consequently the communication of powers will be to each *The quantity and force of fire computed.*

Plate III.
Fig. I

each other as the spaces. Suppose a sphere A, full of air hotter than the other ambient air contain'd in a larger concentric sphere B, the quantity of fire, and the power arising herefrom, on each part of the circumscribed sphere, will be as the space of the circumscribing part to the place circumscribed, which a geometrician will easily calculate: so that as to this property of fire the case is manifest.

C O R O L L A R Y III.

Fig. II.
By an example.

139. To make this plainer; suppose a geometrical sphere A, full of fire, and in contact with another equal one B, suppose the centre of the first to be C, from which draw a tangent to the other sphere CD and CE, 'tis evident that the fire from the sphere A can only come to the sphere B, from the sector AFG, whose proportion to the whole sphere A may be found, as also the magnitude of the cone CDE, and of the spherical segment DIE; which will give us the quantity of fire communicated to this segment.

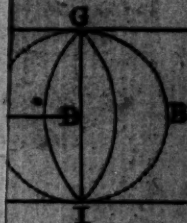
140. The geometricians will easily demonstrate this from their principles; it will suffice us to have indicated the thing.

C O R O L L A R Y IV.

A more exact
computation.

Fig. III.

141. Thus much being understood, suppose some physical cause proper to direct all the fire existing in such sphere in parallel lines, towards some one quarter; it will follow that its whole power will go in that direction, viz. in this proportion, that passing thro' the cylinder EFGI, it be wholly spent upon the sphere KGIB, and thus impart its whole power to the same; so that the effect of the fire thus directed, in respect of the former, will be as the whole to a part; and as a parallel direction to a diverging one; and consequently, by a combination of causes, will produce a much greater effort than the former. But fire increased in a duplicate ratio immediately conceives an incredible accession of force; for 32 degrees makes water freeze, whereas twice that quantity, viz. 64 degrees, renders the air to us hot, and thrice the quantity, or 96 degrees, exceeding the heat of the human blood in a healthy person, becomes mortal to most, if not all animals; and six times the quantity, or 216 degrees, surpasses the heat of boiling water, which dissolves and destroys the solid parts of all animals whatsoever. Since then the area of a great circle of this sphere, is to the whole surface of it, as 1 to 3, the fire will be three times more compact at the base of the same cylinder, than it was before at the surface of the sphere; and consequently its power will be increased suitable. If then it were exactly known how much the expansive force of fire is increased, proportionably to the lesser spaces into which it is condensed, the rest might be computed; since if these were as the area, the force would be triple, on account of the quantity, and triple again, on account of the expansion; and consequently from both together nine times greater than before. It may be worth while, therefore, to try by experiments, whether the expansive power of fire, with regard to its density, may not be determined. This is apparently very great; and consequently such direction of fire into a parallelism will be of great efficacy.



Corus in Contact.

*contact.
ting their Centers
to CKD
to EG.*

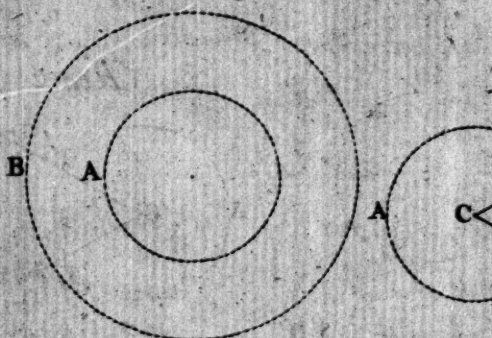
*Fig. 4. see pag.
320.*



*or Glass Receiver.
Using a fire coal.
dip for firing
in.
or Bricks for the
and on
lame of the*

Plate III. see pag. 256.

Fig. 1.

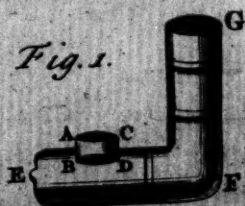


I A. A small Sphere.
B. A larger.

A FIG. 1
Spheres
CDCE
to D &
C FG.

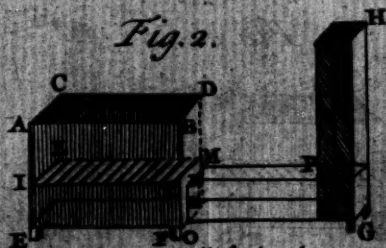
Plate IV. see pag. 309.

Fig. 1.



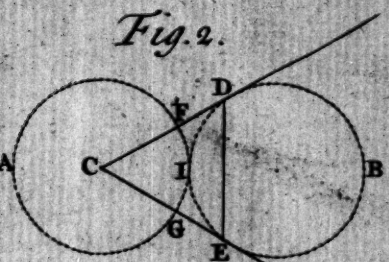
ABCD. A hollow Iron Cylinder.
BD. The Grate.
EFG. The Funnel.

Fig. 2.



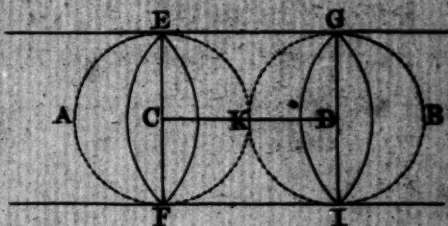
ABCDEF. A hollow Parallelepiped.
ILKN. The Grate.
EM. A Cavity under the Grate.
NO. An Oval Aperture.
NOGH An hollow parallelepipedal Iron Tube.

Fig. 2.



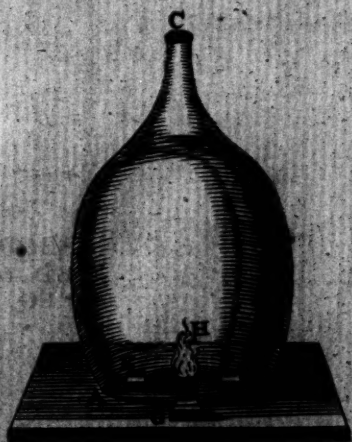
AFIG. BDIE. Two equal
Spheres.
CDCE The two Tangents
to D & E.
C F G. The Sector.

Fig. 3.



AB. Two equal Spheres in Contact.
C. The Centre of A.
D. The Centre of B.
K. The Point of Contact.
CKD. A straight Line uniting their Centers
EG Another parallel to CKD
FI. A third parallel to EG.
EFGI. A Cylinder

Fig. 3. see pag. 318.

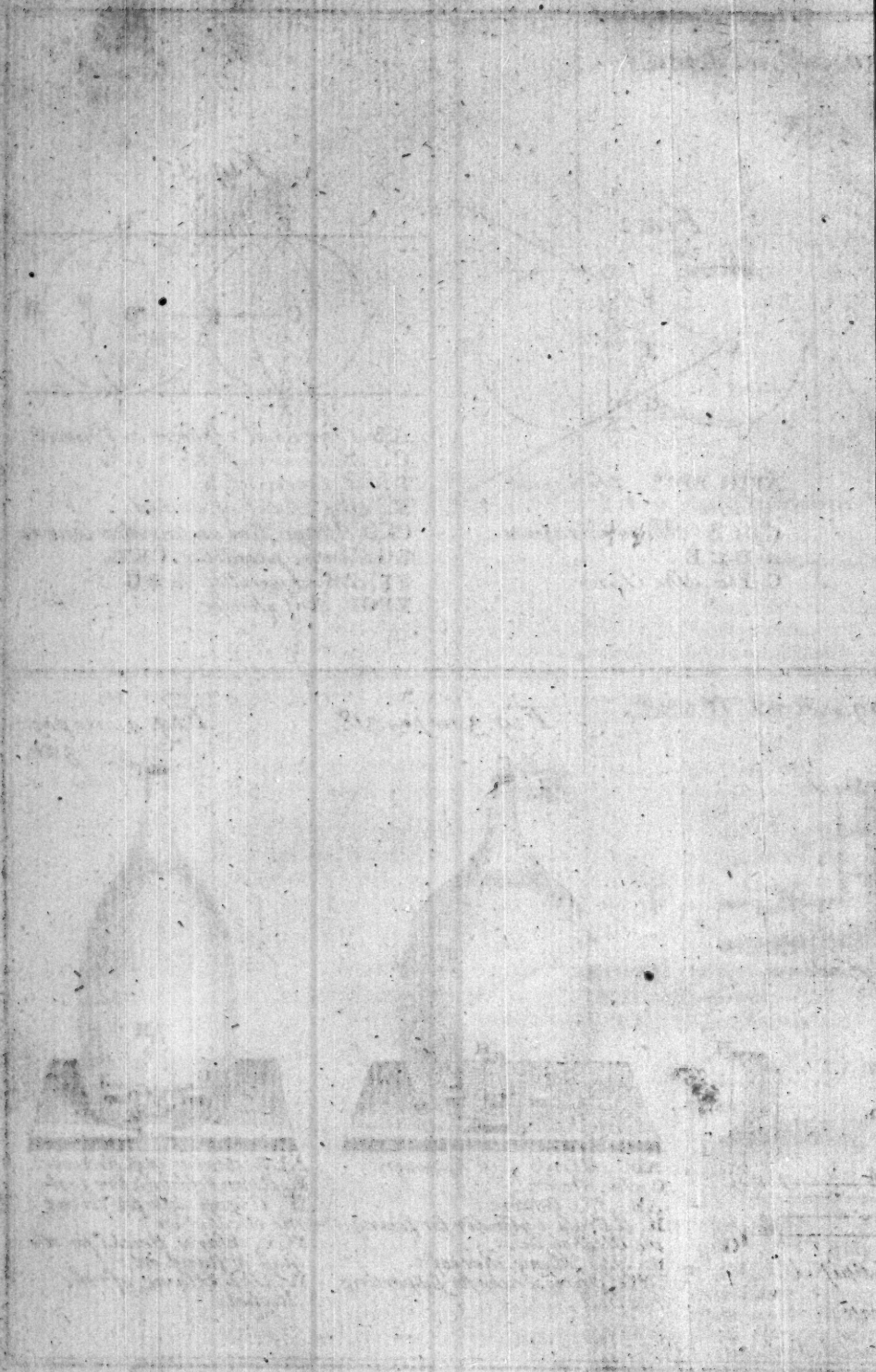


ABC. A large Glass Receiver.
C. The Mouth.
AB. The Bottom.
D. A Brass Cylinder for firing
the Alcohol in.
H. The Flame thereof.
EFG. Three Bricks for supporting
the Bell.

Fig. 4. see pag. 320.



ABC. Another Glass Receiver.
E. A Pan holding a fire Coal.
D. A brass dish for firing
the Alcohol in.
FGI. Three Bricks for the
Glass to stand on.
H. The Flame of the
Alcohol.



EXPERIMENT XII.

140. If we look around, and consider the bodies which seem capable of directing the fire in our air into such a parallelism, it manifestly appears, that the sun possesses such power, to a degree beyond all others (p). For that vast globe, which astronomers make 13431 times bigger than our earth, and almost 12543 diameters of the earth distant from us, as it undeniably diffuses light and heat to us in right lines, considering the immense distance it is at, acts among us as if in parallel lines. We need not produce considerations from optics, catoptrics, or dioptrics, to shew that the rays of light emitted by the sun always pass in right lines; and that when inflected after the point had diverted them, they again proceed in right lines as before. But one experiment occurs, which seems evidently to shew, that all the rays emitted or determined by the sun, always affect to proceed in right lines. If a person,

(p) "The sun, according to that excellent chemist, the younger Lemery, seems to be no other than a huge mass, or collection of the matter of fire, or light; though placed at such a distance, as to disable it to act on bodies here on earth, otherwise than by one of these two ways; viz first, by emanations or emissions of his own substance, transmitted hither: but this hypothesis being subject to great difficulties, and not sufficiently answering to certain phenomena, recourse is had to another; which supposes trains of fire, or light, disposed in all the interstices of the grand expanse of air and æther between the sun and us; and that these trains are made to act on terrestrial bodies, by their being vigorously driven, or impell'd towards such bodies, by the immediate action of the sun thereon. These trains in effect may be esteem'd as a sort of little suns prolonged, but always depending on the great sun, as the source of their motion, and action on bodies: 'tis these that form the rays of light; they do not, in point of matter, differ from the substance of the sun himself; but only in this, that the same thing is more copious, in one case than the other. In the sun we may suppose the matter of light more abundant than in the focus of our largest burning-glasses: Thus, from the vehement action of the rays of the sun, collected in such glass, we learn what use the air interposed between the rays of light is of, in tempering their action, and rendering it more supportable; since, without such medium, instead of warm-

ing, and illumining, it would blind and burn us. So that the air may be consider'd as having somewhat of the same effect, with respect to the rays of light falling upon us, that the water in a *balneum marie* has.
"The sun and stars, according to Sir I. Newton's conjecture, are no other than great earths, vehemently heated: for large bodies, he observes, preserve their heat the longest, their parts heating one another; and why may not great, dense, and fixed bodies, when heated beyond a certain degree, emit light so copiously, as by the emission and re-action thereof, and the reflexions and refractions of the rays within the pores, to grow still hotter, till they arrive at such a period of heat as is that of the sun? Their parts may be further preserved from fuming away, not only by their fixity, but by the vast weight and density of the atmospheres incumbent on them, and strongly compressing them, and condensing the vapours and exhalations arising from them. Thus, we see that warm water, in an exhausted receiver, shall boil as vehemently as the hottest water, open to the air; the weight of the incumbent atmosphere, in this latter case, keeping down the vapours, and hindering the ebullition, till it has conceived its utmost degree of heat. So also a mixture of tin and lead, put on a red-hot iron in *vacuo*, emits a fume and flame: but the same mixture in the open air, by reason of the incumbent atmosphere, does not emit the least sensible flame†."

* Mem. de l'Acad. an. 1713.

† Ibid. Optic.

son, about twelve o'clock at night, in the middle of winter, at the time of new moon, in a very cold season, and a clear sky, look towards the heavens, he would see nothing bright in that vast expanse except the lesser stars; the sun shewing nothing of his heat or light through the whole visible hemisphere, excepting the little that is reflected to us by the planets: and yet at that time the rays of the sun are diffused through the whole hemisphere, and illuminate it accordingly, excepting only that little cone in the immense space, whose base is a great circle of the earth, and its axis 114 diameters of the same; which little inconsiderable tract is the only one in the shadow of the earth not illumined by the sun. Hence it manifestly appears, that tho' the sun's light fill any space ever so plentifully, yet it can by no means be perceived by a person so placed that right lines drawn from the sun's body, cannot come to his eye, unless the rays be reflected from some other repelling body, which receives the rays in strait lines from the sun. This may be shewn still better in a chamber closely darken'd on all sides, so as not to admit the smallest light; if then a small part of the sun's rays be admitted into the chamber through a minute aperture, there will be one lucid cone produced in the space of the chamber, whose vertex will be in the aperture, and its base projected *in infinitum*: if then a black body be opposed to the base of this illuminated cone, no light will appear in the chamber, except to an eye placed within the cone; which eye, if placed ever so little out of this, will see nothing, even though the whole cone be certainly illumined. It must be own'd, that a person placed a little aside of the cone will see somewhat, though very faintly; but if we consider the reason thereof, we shall find this wholly owing to the dust floating in the air, which reflects some rays all-around; and that if this were away, there would be no visible light at all; as plainly enough appears, when at the time of observation, the dust happens to be so disposed as to reflect no light: by all which it appears, that the rays of the solar fire naturally act from the centre to the circumference in parallel lines.

Farther illustrated.

141. If now we consider, that all objects visible, by light, but obscure in themselves, immediately begin to shine, or be seen, as soon as the rays determined by the sun can fall upon them in right lines; and disappear at the same time, if the passage to them in right lines from the sun is obstructed; and especially if we consider that the rays falling from the sun upon a perfect plain speculum, and reflected thence according to certain laws, will again only illuminate that side towards which they are reflected, the doctrine above laid down will be still further confirmed. And thus much we clearly learn from dioptrics, that a ray emitted in a straight line from the sun, falling on a clear speculum, and reflected therefrom in a straight line on another similar speculum, will be again reflected; and thus the same ray, how often soever, reflected still retains its shining faculty, and is only visible, in a right line drawn from the lucid point of the last reflecting speculum to the eye; and since this equally obtains in the whole image of the sun, as in one point thereof; it appears that the power of fire, as determined by the sun into parallel right lines, still continues as long as the radiation, or reflection continues; but as soon as the illuminating sun retires, this

this determination in right lines immediately also ceases, and the fire returns to its native tendency to expansion; so that the sun appears again as the director of fire.

142. If we reflect again, that the apparent image of the vast sun, on account of its great distance, appears only a lucid orb, whose diameter fills the

$\frac{61}{43200}$ or $\frac{1}{708\frac{12}{51}}$ or $30' 30''$ of the visible circle of the heavens; we shall find

that his rays projected thence, on account of the smallness of the space wherein our observations are made, may so far be reputed as parallel. Lastly, the same may be further confirmed hence, that both in optics, catoptrics, and dioptrics, the rays of light are always supposed to issue in parallel lines from the sun; and this in the most accurate computations of the course, reflections, and refractions thereof, whereby the true points of the foci, reflections, and courses are determined; so that all phenomena confirm our doctrine.

143. To sum up the whole in short, it appears that the sun is a cause, *Concluded.* which, whenever it can act without any impediment on the matter of light lodged in the air, instantly drives it into parallel rays.

144. But it has also been observed in all ages, that these lucid and parallel rays of the sun, likewise produce heat in the bodies they are directed upon; so that what we have shewn concerning light, holds with equal evidence concerning heat. And as we here speak of that heat which is found by thermometers, it again follows, that the same will also hold good concerning true fire, which we have hitherto been speaking of. We have therefore found the true cause, whereby the sun, by his direct action, can make so considerable an increase in the force of fire known by expansion, by merely directing the rays without any addition of new matter, or any emission of fire from the body of the sun itself, or any generation of fire out of what was not fire before: a discovery which must be allow'd of great importance in a treatise of chemistry.

145. If then it be asked, why upon lighting a candle, which also determines light in right lines, it does not at the same time heat the place which it illuminates; the answer is, that the small radiant cone does not direct the rays into a parallelism, but diffuses them into a sphere; by which means the fire contained in the chamber, does not act towards any one part, but towards all around: but if you approach so near the candle, as that the nearness create as it were a kind of parallelism, the heat will also be perceived there. This seems to remove all difficulties, and especially if we consider withal, what has been above delivered concerning the great diversity of light and heat.

COROLLARY I.

146. Hence, therefore, upon intercepting the rectitude of the rays, which direct the fire from the sun into a parallelism, such parallelism immediately ceases, and at the same instant the particles of fire diffuse themselves equably all around; which plainly shews, that the whole effect was before owing to that parallelism. *Upon altering the parallelism, heat ceases.* For suppose a burning concave opposed directly to the sun

at noon-day, and in clear weather; and let a body, for instance a rod of iron, be exposed to the focus, and while this is undergoing the utmost violence of fire, let an opake body be interposed between the sun and the focus of the concave, large enough instantaneously to shadow the whole area of the concave; and the effect is, that the whole burning focus will be immediately extinguish'd, though the air between the shadow and concave be equally hot, that is, equally full of fire, and the sun shine equally as before, merely by reason the direction is taken away. Nor can it be alledg'd, that there is more fire between the concave and the focus, while the sun was acting straight upon the concave; since there was evidently no more heat at that time than afterwards, except what came from the reflection. There appears, therefore, a wide difference between the heat produced by the attrition of bodies, and that produced in the air by the solar parallelism; as the former continues a long time, whereas the latter vanishes immediately; tho' when the sun has once heated a body, it retains its degree of heat a considerable time, proportionably to its solidity.

*Green-houses,
how to be
built.*

147. What we have above said has been often experienced by the gardeners to their great cost; in the building of their green-houses; for if the windows thereof, whereby the warmth of the winter sun at its elevation between ten o'clock and two, is admitted, be so order'd as that the rays cannot reach to the cieling of the room, but declining downwards leave a space between the cieling and the part illumin'd by the sun; there is always observed a more intense cold, other circumstances remaining the same; and the cold moisture collecting thereon, will trickle down and destroy the tender plants: for which reason the green-houses exposed full to the south should always have their glass-windows erected to an angle of fourteen degrees thirty-nine minutes to the pavement; and the cieling to be so built, as to decline downwards from the horizontal line, drawn from the height of the windows towards the hind-wall, by an angle of 20 degrees 30 minutes, in those countries where the elevation of the pole is $52\frac{1}{2}$ degrees. The reason is easily deduced from astronomy and dialling; and may here, for brevity's sake, be omitted.

COROLLARY II.

*The degree of
fire by paral-
lelism, com-
pared with
that by at-
trition.*

148. The greatest fire in our air, and of bodies heated by the action of the sun producing a parallelism, is always much less than that found in the body of a healthy man, produced by the principle of life; the latter usually rising to 92 degrees on the thermometer, but the former rarely to 84 degrees: nor does it ever continue long at such height, but presently declines. But we are here speaking only of that heat produced in an open place, without help of reflection or collection, by the mere means of the rectitude of the sun's rays: for clouds by their reflexion, and watery globules lodg'd in the air, by their refraction may much increase the action of this fire; and yet we never heard of such a fire produced by parallelism, or by natural reflections and refractions, as sufficed to kindle alcohol, oil, sulphur, or gun-powder; excepting only lightnings, of which we shall speak hereafter; and this will hold

hold true even of the natural heat under the equator, and all parts of the torrid zone. Whence it appears, that the greatest force of the sun is not able to heat any known bodies, to such a degree as to burn or kindle a live flame in them, and thus produce a spontaneous conflagration; lightening alone excepted. And consequently, it hence also appears, that the sun is never so hot, in the most sultry region of the earth, as to produce fire equal to what a moderate attrition will presently raise in the coldest country, and the coldest bodies. For if iron be thus rubbed against iron, it soon heats to a degree sufficient to kindle sulphur, or gun-powder cast upon it; and yet without affording any light: from whence we also learn, that it is no wonder other bodies may become lucid, though without being much heated; and that there is no necessary connection between a body's shining much, and being very hot. For the light of a winter's sun, about noon-day in a clear sky, affects the eye so strongly, as to blind it for some time; though its heat, under the same circumstances, is not sufficient to melt the thin icicles suspended in the air, and directly opposite to it; as I myself observed this winter. The image of the sun, reflected from polished gold, silver, brass, iron, tin, or glass, yields a glitter, which the eye can by no means bear, yet affords no heat perceivable either by sense, or the thermometer: from whence again, we conclude that there is a great difference between the nature of light and heat, or between lustre and fire.

COROLLARY III.

149. By this means the wise author of all things has provided, lest the sun's rays coming straight upon us, might destroy the tender bodies of animals and vegetables; I say straight upon us, that no one may imagine I speak of reflected, and thus of collected rays, which by such means sometimes become far more violent, and render places uninhabitable; as in the island of *Ormus*, where the white mountains of salt, under a certain aspect of the sun, reflect the rays so fiercely, as to render the place at that time unsufferable: but such excessive heat of weather does not continue long; being soon temper'd by the ensuing cold.

The sun's heat rarely destroys animals or vegetables.

COROLLARY IV.

150. If, therefore, the sun act on the atmosphere, at a time when all the corpuscles floating in it are disposed to an equable transmission of the rays, all the fire in the atmosphere would act in parallel lines, excepting that part hid in the conic shadow of the earth; but it is hardly credible this should happen on various accounts, but much more likely there should be at all times both reflexions, refractions, collections, and dispersions, within the same. And thus I have, accordingly, observed the sun's force and effect on the atmosphere, and the earth, to be always surprizingly diversified; but in those places, which are out of the atmosphere of our earth, the fire directed by the sun should always seem to be proportionable to the spaces themselves, we mean in regions not far from each other.

Yet is not the same in different places.

COROL-

COROLLARY V.

*For several
reasons.*

151. Hence it appears no way probable, that the same degree of fire should ever be found in two different places. For, whether we consider the different aspects of the sun with regard to the earth, or the different constitution and motion of the bodies floating in the atmosphere, or the different disposition of the air at different altitudes of it, or several other matters; we shall always find, that nothing appears more solicitously provided against, than that the same effect of fire should be found at different places.—The force of these causes will appear by the following experiment.

EXPERIMENT XIII.

*And particu-
larly the cold-
ness of bodies.*

152. If this fire determined by the sun, be received on the blackest known bodies, its heat will be long retain'd therein; and hence such bodies are the soonest and the strongest heated by the same fire, as also the quickest dried, after having been moisten'd with water; and it may be added, that they also burn by much the readiest: all which points are confirm'd by daily observations (g). Let a piece of cloth be hung in the air, open to the sun, one part of it dyed black, another part of a white colour, others of scarlet, and diverse other colours; the black part will always be found to heat the most, and the quickest of all; and the others will each heat the more slowly, by how much they reflect the rays more strongly to the eye; thus the white will warm the slowest of them all, and next to that the red, and so of the rest in proportion, as their colour is brighter or weaker. This is well known to the nations who inhabit the hotter climates; where the outer garments, if of a white colour, are found best to preserve the body from the scorching sun; and black ones, on the contrary, to increase the heat. And it has often been observed by the makers of woollen cloth, that if at the same time and place they hang out two wet pieces, the one black, the other white, the former will smok and dry quickly, but the latter retain its water long; and cloths of other colours will dry so much the slower, by how much their colours are the brighter.

153. It has also been long ago observed, that all black bodies are sooner kindled and set on flame by the same fire, than those of any other colour. The dust of white touch-wood will hardly catch, and sustain a spark of fire struck on it; whereas if the same be struck on a black coal, the dust hereof will readily receive, and keep it up, so that in a short time the whole dust will be on fire. The purest and whitest linen will hardly maintain a spark thrown on it; but if the like spark be cast on tinder, which is only the coal of linen kindled, and again extinguished, it will immediately catch through

other (g) This extraordinary susceptibility of heat in black bodies, Sir *I. Newton* accounts for hence, that the rays of light falling on them, are neither reflected from them, or transmitted through them; but, entering the bodies, undergo a great number of reflections

and refractions within, till their motion be spent, and, consequently, their heat, &c. lost; *i. e.* according to him, till they cease to be fire: but what motion and heat they themselves lose, the body receives.

through the whole body of it. Nor would gun-powder, were it not for its black colour, be so easy to kindle; as appears by the powder made of white nitre ground with sulphur. The gardeners have long complain'd, that their white soils would not warm with the sun, except in the very outmost surface; whereas the black grows so hot, as to burn the roots of plants. The chemists have long ago observed, that black bodies, when committed to digestion, or reduced to blackness by art, easier grow hot by the same fire, in the *caput corvi*, *collum cygni*, or *cauda pavonis*, which require different degrees of fire. Lastly, the philosophers have confirmed the matter by experiments. If a piece of white paper be laid on the focus of a burning-glass, it will be long before it heat, and very long before it take fire; and as soon as kindled, quits its whiteness, turns brown, and then black; immediately after which it catches flame: whereas, if a black paper be laid on the same focus it immediately takes fire. We have some extraordinary things on this head in the experiments of the academy *del Cimento* (r). Hence we see the reason of many phænomena in meteors; it being a known point, that thunder and lightning are never found more furious than in dark weather, when the heavens are cover'd with black clouds; from whence usually arise terrible whirlwinds, by the rarification of the air, occasion'd by the sudden immense production of heat.

EXPERIMENT XIV.

154. Black bodies do not reflect or throw off the light, how strongly so ever it strike on them, as we found by the following experiment: Smearing a strongly-burning glass over with the smoke of a burning candle, till it was quite black, and then exposing it to the sun, an eye, placed in the focus, could not perceive either the least light or heat therein, or any other mark of fire; but no sooner was the smoke quite clean off, and the glass restored to its former brightness, than upon exposing it to the sun, it had recovered all its power of shining and burning. Hence it is, that sore eyes are not offended with black colours; and those affected with the *ophthalmia* have no relief from any colour, equal to that of the privation of all colours, viz. darkness. So *Tschirnhaus's* burning-glass, if covered with a thin fuligo from the smoke of a burning candle, and thus opposed to the hottest sun, will neither produce heat nor light in the focus thereof.

Black bodies return not the light they receive.

155. From all which it plainly appears, how small a matter in the air may often suffice to prevent the greatest effects of fire produced by the sun; and in the mean while, how different a degree of heat the same cause may produce in different places; wherein it is very remarkable what effect a slight coat or cover of blackness will produce.

156. But the whitest bodies reflect the light which they receive with nearly the same force as it struck them: this clearly appears from a white metal; e. gr. pure solid silver, when formed into a speculum, which will retain

White ones do.

(r) Sagg. Esperienz. 266, 267.

retain the sun's image, almost with equal vigour as it received it; so as to dazzle and hurt the eyes, and prove intolerable where the eyes are inflam'd. Thus if we view a clear plain glass opposite to the sun, we shall find it transmit the rays seemingly without any alteration: but if we view it with the eye placed directly against the sun and the glass, we shall see nothing in it; yet if the hind-part of the glass be cover'd over with quicksilver and tin, mixed in a certain proportion, which afford an exceeding white coat, the sun's image will immediately appear in it in all its lustre, and be reflected from it with intolerable brightness.

*So do yellow,
and other
colours.*

157. The yellow glittering of gold is also known to reflect the sun's rays with great strength; but this is no where more conspicuous than in a concave speculum form'd of wood, exquisitely turn'd into a spherical concave figure, and thus polished, and exactly cover'd over with gold-leaves; the incredible effect of which, in burning bodies, has lately been seen in *Saxony*. Nor can it be supposed, that this is owing to any property in the metal; as appears from another still more extraordinary speculum, which burns vehemently, and yet is made of pieces of straw artfully interwoven together.

158. Thus red, and all the other capital colours defined by Sir *Isaac Newton's* theory, may be examined both with regard to the light which they collect in the focus, and the fire and heat, which they produce in the same; for if speculums be made of the same matter, magnitude, and form, polished also in the same manner, but their surfaces of different colours, and thus exposed to the sun, the different powers of the fire collected in their focus's, will give us a view of the effects of the colours, with regard to the generation of fire; and at the same time shew which colours will heat, which cool, and which temper, or mitigate the same; which reflect the fire, which retain, and which dissipate it. It may suffice for our purpose, just to indicate these things; we proceed to a further examination of fire.

C O R O L L A R Y I.

*How far the
power of
burning-
glasses may
be owing to
colour.*

159. From what has been observed, it will be easy to conceive the doctrine of burning speculums, so far as their power depends on the colour of their smooth polished surface: a few experiments, carefully made, may sufficiently ascertain how far the colour of the speculum contributes to the force of its focus.

C O R O L L A R Y II.

*The heating
and cooling
colours.*

160. Nor will it be less easy to conceive the foundation of the force of fire, by enquiring what colours are to be laid on bodies, in order to learn what effect, as to heating and cooling, will arise therefrom. For thus much may be learn'd from the colour of the ground we tread on: a black earth burns the feet, but spares the eyes; walking on a white one scarce warms the feet, but is troublesome to the eyes. The same may be observed with regard to paintings and hangings; and hence we have a hint for the making proper shades to keep heat from the body, and the blaze of light from the eyes. 'Tis certain that houses white on the outside, are cold on the inside;
and

and those black on the outside are hot on the inside; supposing the matter and dimensions of the walls the same. Covers for the head, white on the outside, but the lower brim black, afford a great relief to the head in a scorching season.

COROLLARY III.

161. Upon the same accounts we find the ground intolerably hot, where the soil is black, and exposed to a brisk sun. In some parts of the earth, the air itself is so hot, that it can scarce be endured; as is particularly observed in the island of *Ormus*, where a chain of white mountains, running from east to west, reflect the light so strongly, that men have no way to preserve themselves from the extreme heat hence arising, but by lying and sleeping under water, with their heads only kept above it. The like is found at *Gamron*, occasion'd by a white sandy mountain, which reflects the rays so vehemently, that though these places lie without the tropic northwards, the atmosphere is scarce found so scorching in any other part (s).

The cause of heat on the earth, and in the air.

COROLLARY IV.

162. Water and other fluids are raised in the atmosphere, either by force of the terrestrial or aerial fire, and are brought to recede from each other by the same fire, the more easily, by how much they are pressed with a less weight of atmosphere; consequently the higher they ascend, the further they still recede from each other, both on account of the enlargement of their spaces, and the diminution of their reciprocal attraction. Thus there will be continually a less attrition between them, and consequently the less fire will they collect about them; they will grow colder, and float about thro' the immense spaces of the atmosphere; which will still give them the less assistance, the higher they are. While thus agitated, the watery parts are probably resolved into their atoms, which singly are perfectly hard, rigid, and immutable; but when reunited, constitute a soft water, as before. And as soon as, from any cause, several particles of watery vapour begin again to unite in this upper, and consequently colder part of the air, 'tis probable the air becomes filled with a multitude of little slender icy shivers; which when they begin to descend, and in their progress nearer the earth begin to be collected into less compass, reflect the rays of the sun which fall on them, and thus form the appearance of white clouds; which the whiter they are, the more certainly do they prognosticate snow, hail, cold showers, and winds; but the whiter the face of such a cloud, opposed to the sun, does appear, the colder always will its hind part turn'd from the sun necessarily be found; as being destitute at that time of the sun's heat. Hence it follows, that such clouds may increase the heat of the air, in a short time; especially when by their various positions, in respect to the sun, they happen to project his reflected rays upon some small part of the air, and thus form as it were a kind of focus; but if black clouds be seen in the sky, at the same time that the sun shines, thunder and lightning usually soon follow.

Meteors substance.

(s) See *Nieubof. Itin. Terr. & Mar.* from pag. 80. to 91, and others.

COROLLARY V.

Whence heat
and cold in
the atmosphere.

163. After what has preceded, we can no longer wonder how such sudden vicissitudes of heat and cold should sometimes arise in a certain part of the atmosphere. For if we consider, that at the same time, when the sun strikes the air directly, the fire in it is immediately driven into parallel beams, though vaguely dispersed before; this gives us one great cause of the increase of heat. If we again consider, that the ground on which we tread, becomes suddenly exposed to these parallel rays, it must also heat quickly; lastly, that all bodies in this air, or upon the earth, will also be heated more and more by the irradiation of the appearing sun: from whence it follows, that the heat in a certain place may be increased as above mentioned, though not a single particle of fire should be added to what was in it before. So that we have found another manner of exciting latent fire; viz. by the action of the sun impelling the particles of fire, so as to make them proceed in parallel lines.

EXPERIMENT. XV.

Parallel fire
collected to a
focus.

164. If now we conceive, perfectly white polished minute bodies so accommodated to each other, as that fire, when render'd parallel by the sun's action, and directed on the surfaces of such bodies, so as that all the rays reflected from them unite in one small point, all the fire will then be collected in such place; which fire, otherwise, if the bodies had been disposed parallelly in the same plane, would have been driven into a parallelism as it fell. Whence it follows, that the fire in this point, which we shall hereafter call a focus, will be so much the stronger, on account of the increase of its quantity, by how much such point or place collecting the rays, is less than the whole sum or space of the surface of the reflecting bodies: and this fire, as now increased by parallelism, has been described in the preceding articles.

In a parabolic
concave: if
practicable.

165. If therefore, we could make a concave speculum, whose cavity were form'd by the revolution of a perfect Apollonian parabola about its axis, and consequently should have perfectly the figure of a parabolic conoid; and supposing the matter of such speculum also to be very dense, as gold, and its colour white, as the finest mercury; and lastly that it be exceedingly elastic, as the finest steel, and its aperture or base very large, we should find, that in the point of the axis of such speculum, distant $\frac{1}{2}$ part of the *latus rectum* from the vertex, the whole power of the fire, which enter'd in a parallel direction, within the circular base of the parabolic conoid, placed parallel to the face of the sun's disk, will be connected, and consequently, by increasing the magnitude of the speculum, this force may be still further and further augmented. But human industry has not yet been able to discover such a matter, nor to give such a figure to a concave body; so that the excellency here spoke of is hitherto little other than ideal.

166. The

166. The next view after this, is to chuse the most solid, white, hard, elastic matter, and to polish it thoroughly, so as to leave no inequalities on its concave surface, and give it a spherical figure, which was supposed practical by turning and grinding; but neither has this been found practicable, on account of the difficulty of the polishing: fire, after this manner may be raised to an incredibly violent degree.

167. Not to enumerate all the other contrivances, it may suffice to consider the best which has hitherto been produced; being that made by the two *Villettes*, father and son, of *Lyons*, with great expence and infinite labour. It is made of a metallic matter, whose due mixture was discover'd by a multitude of trials; it is ground to a hollow spherical figure, so as the chord of the segment of the circle, by whose revolution it was formed, or the diameter of the circle which defines its plane or diameter, is 43 inches; consequently the area of its plane, whereby the rays are admitted, contains 1452 $\frac{11}{14}$ French inches: its figure is both concave and convex, and either side or face polished with the greatest nicety possible; the whole weighs 400 French pounds. Lastly, the rays determined on it by the sun, when opposed directly thereto, are collected into a circle in the air, of half an inch diameter, at the distance of 3 feet and a half from the bottom of the speculum; consequently the parallel rays of the sun, falling within the circle or aperture of the speculum, on the concave surface thereof, if they be all reflected into the focus, will be contracted out of a space of 7396 into a space of 1; so that the fire will be 7396 times stronger in the focus than it was before in the air. The difference appears excessive; but it must be considered that we here supposed all the rays, which fell on the surface, to be reflected from it, which is found false by experiment; in regard its figure is neither perfectly spherical, nor perfectly smooth and polished, or without inequalities; as appears by the microscope, and even upon looking obliquely with the naked eye. However this be, if we could find the proportion of the reflected to the incident rays, it would be easy to compute the precise increase of fire, without which we can only say in the general, that the fire here produced is extremely violent: for, upon experiments frequently repeated, it has been found that all bodies, combustible by any fire, when placed in this focus, are instantaneously burnt; and even bodies, which by reason of their moistness do not readily burn, till the fire have first dried them, do here take flame immediately; as has been found in a thick piece of green wood, moved backwards and forwards in the focus, which is immediately set on fire, and continues to burn constantly, though moved about; the flame still arising in that part which is exposed to the focus. The six metals melt in a minute in the same focus; as do also all the semimetals hitherto tried. Add that stony and rocky bodies likewise immediately fuse, and after fusion turn to glass. The vehement force it exerts on these occasions may be learnt hence, that in the twinkling of an eye, it melts bones themselves, whose ashes can so powerfully resist the force of fire and lead in the refiner's test; and that it melts and vitrifies tiles, clay, sand, crucibles, marble, jasper, and porphire, instantaneously. Lastly, what no person unacquainted with the hidden force of fire would ever have imagined, the very stones used in the building of

*The power of
Villette's
speculum.*

L furnaces for melting iron, and separating it from the ore, immediately melt and vitrify in the same focus; notwithstanding that such stones might have continued exposed to the fiercest common fire for many years without any change: so that this fire, collected by the speculum, will do that in the shortest time, which the greatest fire we can raise by other means is not able to effect in any length of years; and yet this fire subsists in the thin air, or even perhaps *in vacuo*; the air being all expelled out of the place by the force of fire, which thus remains without any fuel; continuing as long as the sun continues to shine on the speculum.

Extraordinary properties attending it, as that the rays of the moon afford no heat.

168. But the colder the matter of such speculum is, the more violent is the fire always found in its focus; consequently, the denser the metal-line matter is, the greater is its effect: add, that by this coldness, the elasticity is also increased, which makes another addition to the effect of the speculum. In proportion as the body of the same speculum grows hot, its action grows weaker and weaker; hence it is always found more powerful in the winter-time, in clear cold weather, than under the like clearness of air in summer. It has been above observed, that the cohesion of the particles of bodies is continually loosen'd by the action of fire, and this proportionably; which must leave greater interstices between those particles, and consequently lessen their contraction, and the elasticity arising therefrom. This would afford a large field for speculation: but it being impossible for us now to exhaust every thing, we shall only here take occasion to note, that in a clear winter's night, at the time of full moon, the image of that luminary being received directly on the speculum, produces a very bright focus, too vehement for any eye to endure; and yet the ball of a most exquisite thermometer, being applied to the centre of the same focus, affords not the least sign either of heat or cold, but remains perfectly unmoved: which appears the more wonderful, as the rays reflected from the moon's body upon the speculum, were originally directed by the sun; whose image, as mention'd in the former experiments, when received on a plain glass speculum, and reflected directly therefrom upon *Villette's* concave one, produce a fire in its focus, almost as vehement, as if the rays had been received immediately from the sun itself: which affords a new proof of the difference above-mention'd, between heat and light. These are the chief physical effects relating to our present purpose, as they are accurately deliver'd by the excellent author himself; the use whereof will be presently shewn in prosecuting this subject.

Conveniences and inconveniences of Villette's speculum.

169. One inconvenience is found in this noble instrument; *viz.* that requiring the sun to be of a good height, in order to receive the power of it, and be directly oppos'd to it, so as the axis of the disk of the sun, and of the concavity of the speculum be in the same right line, it thence becomes necessary for the bodies to be tried in its focus, to be placed in the same line; by which means they cannot be prevented from falling down as soon as fused; whence they escape the further action of the fire, and cannot be brought under any new trial after melted: which on many occasions would be highly useful. But this inconvenience is in some measure compensated, in that the external surface of the polished metal causes

all

all the reflection, and thus does not dissipate or change the rays; whereas glass speculums, made to reflect by covering them over with mercury, dissipate many of the rays by the multiplicity of images produced by the different positions, or transparent particles of glass: and other ways of producing the like focus's, by refraction of the rays produced by transparent bodies of proper figure, act still more faintly; in regard they at the same time reflect a great quantity of the rays in all directions, and absorb and suffocate many others in the obliquity of their pores.

COROLLARY I.

170. From a consideration of what has been above delivered, it evidently follows, that the heavenly bodies, both planets and fixed stars, make no sensible alteration in our fire as to heat and cold; for, to omit the sun, whose effects we have been above relating, the moon is the only one whose image received on this speculum, and after reflection collected into so narrow a compass, produces not the least sign either of expansion or contraction in the air; from whence it will easily follow, that the light of the other planets must do still less: neither has the light of the fixed stars any effect in the like case. If therefore, which does not appear improbable, these bodies have any influence on the heat or cold of our earth and atmosphere, it will necessarily follow, that they must act after some other manner than by the emission of rays of light. Nor will it avail the astrologers to alledge the various aspects, conjunctions, and constellations of the stars; it being evident, from the above experiments, that these make no alteration therein. So that we may therefore conclude, that all the heat derived to us from the heavenly bodies depends wholly on the sun; no other known body having hitherto been found to contribute thereto.

The sun of all the celestial bodies, increases fire by parallelism or reflection.

COROLLARY II.

171. Upon considering these things, it will not be so easy to conceive the remarkable changes produced in bodies by the stars: in regard most of those known to us are accompanied with heat or cold at the time they produce their effects: it follows, therefore, that the influence which the stars are supposed to have on these sublunary bodies, must arise from some other causes which are not owing to fire; whence also those vicissitudes do not appear to depend on the communication or alteration of fire produced thereby. Nor has the power yet been ascertain'd by experiments, whereby those superior bodies affect our inferior regions, unless perhaps it be gravity; which is a very different thing both from fire and light, nor has any dependance on them. This power too is different, according to the different aspect of the stars; whence, in respect of the differences of attraction and repulsion, many changes may be produced in bodies, as no one acquainted with these things will deny.

Celestial influences not owing to fire; possibly gravity.

COROL-

COROLLARY III

Various phenomena of the atmosphere accounted for.

172. From what has been above explain'd, we may be able to account for several phenomena of the air, which on some occasions have strange effects on our chemical operations. It has been shewn by the learned *Halley*, that water is continually evaporating and rising into the air in vast quantity, and that in clear weather it will mount to a great height, as appears by the transparency and the increased weight of the atmosphere; here also it will then freeze, if its particles happen to join in those high places.

173. And what hinders the same, when thus form'd from uniting together in great masses, and thus appearing in form of clouds? And must not these on many accounts be continually changing their figures, and becoming sometimes plain, and then spherical, and so of the rest: and supposing thus much, must not the action of the sun shining through the air, and receiv'd on such specula, and again reflected therefrom, produce many sudden and extraordinary appearances of light? And when again disposed in a different manner and situation, in regard to each other, may not thick darkness immediately ensue by a suffocation of the rays of light? When the clouds are illumined by the sun and moon, so as to appear very white, snow or hail usually ensue soon after; and in a very sultry season, after a long drought and calm, we have observed small white clouds, risen a good height, continually increasing at a great rate; and in proportion as they increase, turning less and less white, till at length, collecting out of a vast extent into a narrow pyramidal space pointed towards the earth, they make a thick shadow, and at last burst down in showers with great vehemence; which falling with large drops, shew they had formerly made hail, while in the higher and colder regions; which, in its descent through the lower and warmer were suddenly thawed: or if the hail stones were too big when above, they fall to the ground in their solid form; on both which accounts they produce a great and speedy coolness in the lower air: all which is easily conceivable from the few simple principles above laid down. For the higher the watry particles were raised, the more icy must they necessarily become; and for the same reason, with the more violence must they fall, when once they begin to descend; their passage being continually accelerated, according to the principles of *Galileo*. Hence a small cloud compared to a bull's eye, appearing in a clear sky in *Asia*, and falling from thence, appears the bigger the nearer it comes, according to the reciprocal ratio of the distances till reaching the earth, it shakes every thing with immense force, forming a whirlwind, and often turning into a tornado, which drives from the centre towards the circumference of the horozintal circle. Does it not appear probable then, that the clear whiteness of clouds is always owing to snow or ice, formed and suspended therein? 'Tis certain, that water illumined by the sun never appears white, excepting when turn'd to froth, snow or ice, unless it receive and transmit the sun's rays very obliquely to the eye. Again, if it be consider'd, that if frozen water, by the concurrence of wind, be gather'd from all quarters into one mass, and thus opposed

opposed to the sun, and the rays reflected from that part of the surface, and by this means the air between such surface of the frozen cloud and the sun, be heated, moved, and rarified, while at the same time in other parts the action of heat and light is very different; or if we conceive that large globe, as pretty solid, and not transparent, the cold will be so much the stronger in the part turn'd from the sun, and the air likewise so much the denser: on all which accounts there will arise a surprizing rotation of the globe, which will be the more rapid as the sun's heat is the greater, the icy globe denser, the cold on the hind part keener, and the fall of the globe out of a high light air into one that is lower, denser, and more resisting.

174. If these things be considered attentively, we shall no longer wonder at those horrible storms which usually succeed long calms; especially if we recollect the great attrition which bodies undergo in falling from a high to lower heavy air; and the vehement heat and fire which must suddenly be produced thereby. It may also be remember'd, that in some parts of the earth an intolerable heat sometimes rises suddenly, which soon after turns into a horrible storm; and it has been observed that this always happens when the sky is interspersed with separate clouds. For if a few snowy or icy clouds, especially if of a large size, be so disposed in the atmosphere as to form reflecting speculums, whose joint effect meets in some one place, which may and must often be the case; 'tis easy to conceive that a vehement heat must suddenly arise in such place, and the air be greatly expanded therein, so as sometimes to produce a great vacuum; which being heated by the fire collected there, the cloud and expelled air will be driven with a violent motion and noise, and thus form a kind of rotatory vortices; presently after which, on a change of the situation of the clouds, the focus being dissipated, the air, snow, hail, water, and other bodies near at hand will rush violently into the void spaces. I have long been of opinion, that the sun's light being repelled from icy clouds, and collected into vast focus's was the chief cause of the many stupendous and destructive effects from time to time observed in the atmosphere. A learned *Englishman* has demonstrated with great subtilty, what the force of common, heavy, elastic air would be, when rushing into a mere *Torricellian* vacuum; and shews, that it would be incomparably greater than that of the most violent wind that ever was known; which scarce moves above 22 or 23 feet in the space of a second; whereas this air would move 1305 feet in the same time (1) Considering then the number, magnitude, density, and different dispositions which these atmospherical specula may be found in; what stupendous effects may not be produced thereby? Hence, lightning, thunder, whirlwinds, storms, thunder-bolts, winds, and other meteors. Hence also we may probably conceive why these rarely happen in a hot season, if the sky is clear, and free from clouds; and why, after the formation of clouds, such surprizing changes so suddenly follow.

(1) *Phil. Transact.* 1686. No. 184. p. 193.

COROLLARY IV.

*Especially
upon great
thaws.*

175. But more frequent and violent effects of this kind never happen than when after a long sharp frost, which has bound up the rivers, and even penetrated the earth's surface to a considerable depth: for if a sudden thaw then take place, it is usually quickly succeeded by a multitude of clouds, uncommon heats, and then by thunder and lightning. The reason is, that the fat vapours and exhalations raised by the subterraneous heat, have long remain'd imprisoned under that covering of the earth; as appears hence, that if the ice of a ditch be broke in the middle of a severe frost, it presently emits warm vapours, and this the more plentifully, as well as the hotter, by how much the frost is harder, and the ice thicker. As soon therefore as the exterior frozen turf of earth is soften'd by warmth, the pent up vapours immediately escape through all the passages they can find, and mounting on high form clouds, which being driven about, and sometimes illumin'd by the sun, produce those effects above described. Hence those violent thunders in *Muscovy*, *Sweden*, and *Denmark* after a thaw. Add, that bodies in the most solid state of cold have still a considerable motion of attrition.

COROLLARY V.

*The heat of
particular
places,
whence.*

176. It may next be considered, that the rays reflected from the earth, or buildings, mountains, and the like, may in some situations, with regard to the sun, produce a much greater degree of heat in one place than in another: it being evident that these, either by design or accident, may be so constituted as to make a great addition to the heat in the centre of the place; and it may be added, that the diversity of colours found in the adjacent bodies, as we have hinted before, may make a great alteration in the degree of heat. Lastly, it must be remember'd, that in the different seasons of the year, a great difference is continually arising in the sun's direction to those bodies; whence continual increases and diminutions, in the reflections, focus's, &c. From all which we may easily perceive whence it happens, that some places on a certain time of the day or year, differ so much from themselves, as to heat, cold, and light. It is well known, that in some countries the morning, in others the evening sun is the hottest: the three points above-mentioned ought here to be considered and examined in their proper places. What most concerns our present purpose is, that either the fire may be render'd greater or less, without any other cause than a mere reflection, and a collection, or dispersion arising therefrom. It is vulgarly imagined, that the heat, *ceteris paribus*, is strongest in high open places, but the contrary is founded on fact; since in clear hot weather the air is cooler and more temperate in a wide extended plain than in the valleys; whence horses and other cattle find themselves best, and move and run more without tiring or blowing on large heaths than in other places. In effect, in such plains there is scarce any heat produced, except from the common impulse of the rays, and their reflections from the clouds: all which things conduce much to a right understanding of fire; which, for want hereof, is falsely imagin'd to be inherent

rent in some parts of the earth more than others; whence many fictions have been entertain'd foreign to the true nature of fire: whereas, all things duly examin'd, fire appears equably distributed in all places.

COROLLARY VI.

177. It may suffice to have thus briefly shewn, that the meteors in the atmosphere, and the heats in the inhabited parts of the earth, with the several effects arising therefrom, all owe their origin, degrees, and vicissitudes, chiefly to a change in the reflection of the sun's parallel rays. *Recapitulation as to meteors.*

COROLLARY VII.

178. It would be a matter of still higher enquiry, as well as of considerable use, to define the true proportion between the quantity of light falling from a given space upon a reflected body, and the quantity of the same collected after the reflection in a focus. Suppose then, the light from a circle two feet in diameter to fall on a concave spherical speculum, and be reflected thence into a circular focus of an inch diameter, the areas of the luminous space and of the focus may easily be compared together, as being in a duplicate ratio of their diameters: whence the mathematicians have also deduced, that incident light is in the same proportion to reflected. But if we consider the thing physically, we shall meet with much greater difficulties than at first sight would be apprehended in the solution of so simple a problem. *Difficult to assign the proportion of fire in the catoptric focus.*

179. For who can assign the number of pores or vacuities in the whole concave surface of the speculum, in proportion to the solid matter, by whose surface the reflexion is performed; all the substances hitherto used for this purpose being much lighter than iron, and consequently so much more porous than gold, whose real solidity, with regard to its bulk, has not yet been ascertain'd. Hence it appears impossible to fix this matter, which however is absolutely necessary to determine the point required: perhaps not above a millionth part of the bulk of a given body is true matter, and that all other parts may be considered as pores or vacuums; what quantity therefore of the incident light must be lost on this score is easy to conceive. *From the pores of the speculum.*

180. But allowing a perfectly solid body were procurable, how should we then determine the figure of the speculum? For suppose it to be spherical; if it were really so, its inside would be perfectly black, except in the single place of its focus, or in the lucid vertical cone carried on to the focus, or prolonged a little beyond, in diverging and deflecting coloured rays, as follows from the doctrine of the great *Newton*: whereas the bottom appears in every situation. But to give the true figure to the metal, by grinding or polishing, is scarce possible; for if we view the extreme parts, even of the smoothest and best polished speculum, with a good microscope, we shall find it rugged, uneven and porous; and be convinced that only the smallest part of the concavity is of the same figure: the figure of the whole being every where *its figure.*

diversified and irregular; which takes away all hope of discovering the quantity of reflected light.

And uncertain homogeneity.

The power of fire not from quantity alone.

181. But where these difficulties overcome, there is another considerable one still behind; *viz.* what certainty we have that the matter is every where the same, and reflects the light equally, and with the same force in every point of the speculum; for by Sir *Isaac Newton's* doctrine it appears, that there may be a great diversity in bodies in this respect? How do we know, but there is some hitherto unknown matter mixed with the rest, which has no power of reflecting at all, and which extinguishes a part of the rays proportionable to the quantity of this matter found in the mixture. Again, tho' we might discover the quantity of fire in the focus, with regard to the quantity which falls parallel on the surface of the speculum, in each of the three cases above mention'd, yet we should only hereby learn the proportion of the quantity, which would not by any means inform us of the proportional power of the fire, which changes bodies in the focus, to that fire which by the sun's direction fell upon the circular basis of the concave, considered as this also changes bodies therein. The reason is, that it should first be known, whether the particles of fire act by their meer force, multiplied by the number of such parts; or whether the rule will hold, that upon doubling the quantity of fire, its power of acting on other bodies will be doubled; for tho' this be usually taken for granted, there is great room to suspect it: and though it be certain, that a greater quantity of fire in a less space will always act with more force, it is doubtful whether its active power be only increased as the quantity is increased. My reasons are, because certain experiments shew that some bodies act not at all while at a distance; but when brought to a certain degree of nearness, immediately exert certain powers, and produce certain new motions not before observed; and which become still greater and greater, the nearer the bodies are brought to each other: and again when removed to such a distance from each other, as that this reciprocal virtue is destroyed by the distance, all the motion immediately ceases. Of this we have an instance in loadstones, which if one be at rest in any given place, will remain so for ever; but if another be brought gradually near it, you will find a certain point of distance wherein it immediately begins to move and agitate the former; and as you bring it still nearer and nearer, both of them will move still more evidently; the cause that produces the motion being continually increased, as the nearness of the bodies increases; the ratio or ~~measure~~ whereof is hitherto unknown, though for some cogent reasons the great *Newton* suspects it to be nearly in the triplicate reciprocal ratio of the distances.

182. To determine this more accurately, the learned *M. Muschenbroek*, professor in the university of *Utrecht*, has taken laudable pains, not without success. Let us suppose several loadstones of equal power suspended in a spherical surface, at such distance from each other, that they almost begin to feel their mutual powers; and suppose thereby a very slow approach towards the centre of the sphere, as they gradually come nearer each other; an extraordinary kind of motion will doubtless immediately arise in them all, though

though ever so many. But suppose them all remaining at rest at a certain distance, and let one of them be then placed in the centre of such sphere; from that moment a motion will doubtless arise in them all, not one of them remaining in its former situation; and as they again begin to approach nearer the centre, at every new distance another greater motion will be continually perceived, in regard that in every new place a new action will be produced between the attracting and repelling poles. The like might be shewn in air, and numerous other bodies: for our present purpose the single instance above may suffice. If then the like power, or perhaps a greater be found in the particles of fire, it will follow, that upon bringing them close together their action will be vastly increased; which is scarce perceived at all while they remain separate: so that the fire in such focus may acquire a power of changing bodies, much greater than what arises from the bare quantity and number of the particles brought together. In effect, the truth of this has been long found from experiment: for if a thermometer be placed in a cold winter's air at noon-day in a place illumin'd by the sun, it will only stand at 20 degrees; yet at the same time stone will immediately melt and vitrify in the focus of *Villette's* speculum: what effects shall we then expect from it, if a body be applied in the axis of a speculum only 5 inches distant from the focus, where the heat observed is scarce 190 degrees; and it is manifest that such a difference could not arise from the mere difference of density, but that there must be some new agitation produced in the particles by the nearness of their contact. And we have already shewn the proper virtue of fire to be that whereby it expands both itself, and all other bodies it acts upon: it is possible, that this virtue may be vastly increased by the collecting of its particles together; and hence perhaps its power may in a moment be so considerably augmented.

183. Lastly, it does not appear, whether the reflecting power in the parts of the speculum be equally great about its axis, with regard to which the rays fall parallel, as about the extremer parts of the surface of the speculum; and consequently it may be doubted whether all the rays repelled from any point of the speculum, and collected together in the area of the focus, be reflected thither with equal force; so as that the power of the collected rays correspond to the number thereof.

The curvature of the speculum unknown.

COROLLARY VIII.

184. I have had many thoughts concerning the manner of bringing these things to some kind of certainty; and have at length discover'd, that if any part of a speculum be cover'd with a dark opaque matter, yet the rays from all the other uncovered parts will still meet in the same focus, without deviating therefrom; from whatever part of the speculum they came, or whatever part of it were covered. If then we conceive the whole aperture of the speculum covered with a brazen circle, there will be no rays received, nor any reflected; but as we may divide this circle into as many equal parts from the centre as we please, we may by means of a circle thus divided, admit or seclude as many particles of the rays falling on the whole plain as

A way of computing the force of fire.

we please; consequently in this manner we may know the certain proportion of the rays admitted in respect to the whole plain. Thus, for instance, we may admit half the rays, or a third part, or a thousandth part, or any other which we chuse to be collected in a focus; and we may also compare the fire thus collected in the focus, and hence infer whether the power of the fire thus produced be as the number of the rays, or in any other proportion. In effect, by this way we may divide the rays of light which fall on the whole aperture of *Villette's* speculum, in any given ratio in which a circle is geometrically divisible, and thus examine the power of all those fires.

COROLLARY IX.

*By the effect
it produces.*

185. If by proper experiments it be found, that the part of the circle which admits rays, collects so much heat in the focus as is necessary to make water boil therein; and then such another part of the speculum be laid open as produces a heat in the focus, which raises the mercury in the parometer to 424 degrees, we shall then have produced double the degree of heat, consider'd as it discovers itself by the dilatation of mercury; and after the same manner we may try what proportion the aperture of the speculum in this heat, bears to that aperture of the speculum which produced double the heat: by thus comparing the spaces of the apertures, and the effects or degrees of heat produced thereby, we may at length find what the number of rays, and what the uniting or collecting them together contributes to their force; which would be of great importance in the history of fire, and would abundantly evince, that the whole power of fire does not depend on the mere quantity of the rays, but on their closeness to each other. This the few experiments we have had opportunity of making with burning speculums clearly shew; so that the utmost force of fire hitherto known and produced in one simple manner, may now be sufficiently conceived from the quantity of solar rays, transmitted by a circle of 3 feet 7 inches diameter in winter-time. If the same rays had continued on without any obstacle to reflect them, they would only have produced a small degree of warmth in the air; and if they had still proceeded strait on to a thinner air, the heat thence arising would have gradually decreased, and at length perhaps a degree of cold been occasion'd, beyond any hitherto observ'd.—From all which it appears, what wrong notions people commonly have of the nature, and action of fire: it being clear, that the greatest fire ever known to mankind, only differs from the greatest cold, by the action of a reflecting body. From whence we again infer, that fire is equably diffused through all bodies and spaces; but that it exerts no action where there is no body to receive and reflect it. And as the aperture of such speculums may be increased *ad infinitum*, it follows that there is no limit, beyond which the force of fire may not be raised.

COROL.

COROLLARY X.

186. No fire has hitherto been discover'd greater than that in the focus of M. *Villette's* speculum, which surpasses even what is produced by M. *Tschirnhauser's* burning-glasses. Hence, the ultimate effect of any momentary action of fire hitherto observed, is to turn flint to glass; which is done in the focus of *Villette's* speculum: nor has any effect greater than this been ever known. For though lightning will instantly melt iron, it has never, I think, been known to vitrify either stones or metals. It may be added, that this effect of vitrification may be produced in a moment's time, in the coldest place, and the coldest bodies, without any assistance of the sun, without light, and without fuel. Consequently the utmost effect, even of the greatest fire, may be had at any time, in the darkest place, and the coldest bodies. For if in the severest winter's night, a piece of flint and well tempered steel be struck against each other, they will yield live sparks, which will diffuse a vivid glittering light, and yield a hissing noise as they fly through the air. And if these be caught on a piece of clean paper, they will be found to be glass-spherules, form'd of the flint or steel, or both, melted down, and vitrified, and in their rotation through the air turn'd of this figure. Yet the conversion of stones and metals to glass is the utmost effect of the fiercest fire. It appears then, that a momentary friction may act as powerfully as the largest burning-glasses. Consequently, if a huge mass of the best prepared steel were struck against another vast lump of the choicest flint, what an immense fire may we suppose would arise?—Thus much for the other manner of producing a large fire in the shortest time, viz. by the collecting of parallel and reflected rays into a small point.

The highest effects of fire by bare attrition.

EXPERIMENT XVI.

187. If the same fire, driven into a parallelism by the sun, fall upon a transparent well-polished glass, of a perfectly spherical figure, it will be collected into a focus, and burn very fiercely.

The dioptrical production of fire.

188. This has been observed long ago, but never with so much accuracy as in the Duke of Orleans's burning-glasses, in the king's garden at Paris; where divers experiments were made to discover the nature of fire: which will be thought necessary to be here historically related, both as they give a considerable insight into the doctrine of fire, and as their effect was the greatest that has been observed of the kind (u).

189. A spherical glass of this sort, four feet in diameter, and convex on both sides, being opposed directly to the sun, in the summer-season, when the air was clear, and purged of its water by preceding rains, between the hours of nine in the morning and three in the afternoon, made its focus about twelve feet distant from the glass; the focus being an inch and half in diameter: which was that used by M. *Tschirnhauser* himself.

(u) See *Hist. de l'Acad. R. des Sciences*, an. 1699. 90. 1700. 128. 1702. 34.

190. All combustible bodies placed in this focus immediately burn; lead melts instantaneously; and tiles vitrify, if long enough held in it. From a comparison of this with what has been above delivered concerning the force of *Villette's* burning speculum, we may draw the following corollaries.

COROLLARY I.

*Catoptrical
and dioptrical
fire compared.*

191. The diameter of *Villette's* speculum was 43 inches; and consequently its circumference $\frac{946}{7}$. The diameter of M. *Tschirnbaue's* spherical glass was 48 inches; and consequently its circumference $\frac{1056}{7}$. The quantity of rays, therefore, which fall within the compass of the glass, will be to the quantity of those which fall on the speculum, as 2304 to 1849: yet the effect of the speculum is much greater and quicker than that of the glass.

COROLLARY II.

*Catoptrical
the strongest.*

192. Whence it also follows, that catoptrics, if duly improved, would preserve the rays it receives and reflects more entire than dioptrics could do, tho' improved to the highest point: a great number of rays appearing to be lost in collecting them dioptrically.

COROLLARY III.

And clearest.

193. The difference, however, is very great between the focus's of the two. The aperture of M. *Villette's* speculum is $\frac{40678}{28}$ square inches; and its focus $\frac{792}{28}$ square lines. The area of M. *Tschirnbaue's* glass is $\frac{50688}{28}$ square inches; and its focus $\frac{7128}{28}$ square lines. Consequently, the focus of the speculum is to the focus of the glass as 1 to 9. From whence, again, it appears, how much the manner of producing fire by reflexion has the advantage of that by refraction. Consequently the power of fire will be promoted much better by opaque specula, than by transparent glasses; in regard a spherical glass of four feet diameter is the greatest that the glass-man's art has yet been able to produce: whereas the making of specula does not yet appear to have arrived at its utmost pitch; though it must be own'd our expectations from this quarter are not very great. Who can forbear lamenting, that no prince should be found to reward those incomparable artists for what they had done, and hereby animate them to further attempts! Such is the unhappy fate of the finest arts!

EXPERIMENT XVII.

*The greatest
dioptrical fire.*

194. The noble *Tschirnbaue* did not rest satisfied with the success of the foregoing experiment, but applied himself to contract the extent of the former focus into less compass; that by thus collecting the rays still closer, their power of burning might be increased. To this end he made use of a lesser glass, the segment of a smaller sphere, which being placed directly parallel to the former, received all its rays, as they went converging to the focus of the

the former larger glass, and collected them into a circular space, of about 8 lines diameter. So that by this new collection they were reduced from 81 square lines to 16. Hence he gain'd indeed in the closeness of the rays; but by this new refraction lost many of the rays again. On the whole however, the power of burning was considerably greater than before. And here the endeavours of that excellent person stopped.

195. Having now explain'd the capital methods hitherto discovered of producing fire by catoptrics and dioptrics, it remains to rehearse the extraordinary effects produced in bodies by means of these glasses; that the chemists may be convinced there is no need of any gross fire to produce even much greater effects, than any of those wrought in the furnaces of glassmen, assayers, or refiners of metals. Nor will any person except against my relating these after the Academy of Sciences; whose Memoirs are not in the hands of every body: And in treating professedly on the subject of fire, it had been a fault to have omitted them.---The principal are these:

196. (1) Moist branches of green trees, and woods soak'd in water, being applied in the focus, immediately burn and consume in flame, smoke, and ashes. *The principal effects of these fires.*

197. (2) A little vessel of water placed in the focus immediately boils. We wish it had been tried by *Fahrenheit's* mercurial thermometer, whether this boiling water were hotter than water is heated in the usual manner; when it heats in all cases alike.

198. (3) Thin pieces of metal applied in the focus do not immediately melt, but growing gradually hot, at length, run. If they be too thick for the power of the focus to penetrate, they scarce melt thoroughly.

199. (4) Tiles burnt, or dried in the sun, also talc, and other bodies, grow red-hot in a moment, and soon after turn to glass.

200. (5) Sulphur, pitch, and rosin, being covered over with water, melt under it.

201. (6) A piece of slender wood being put under water in the focus, in the summer time, and kept there a while, appears to remain entire, when viewed on the outside; but upon breaking the wood, is found, on the inside turn'd to coal and burnt. This seems to prove, that so intense a fire can only heat water to a certain degree; which being too weak to burn wood, hinders the fire directed under the water from burning the wood in that part contiguous to the water.

202. (7) If the matter intended to be changed, be exposed in a black receiver, the power of the focus is surprizingly increased.

203. (8) If metals, or other bodies examined by this fire, be laid on a coal made of green wood, and not thoroughly dried, they instantly melt, emit sparks, and fly off. Lead and tin quickly melt, and not only fume, but calcine, vitrify, and are lost.

204. (9) The ashes of all vegetables presently vitrify.

205. (10) If any entire large body be applied to the focus, it frequently proves unable to melt it; yet, when ground to powder, easily performs the liquefaction; and when, after this preparation, it still refuses to melt, it is easily made to fuse by adding some salt.

206. (11) Black bodies, and such as remain black in this fire, undergo the greatest change of all others. Bodies that are white when exposed, and which afterwards turn white in the fire, change more slowly, and with greater difficulty; and those which being black at the time of their exposing, and afterwards become white, are the most difficult of all to change; especially if they turn white after fusion.—Lastly, such bodies as remain perfectly white in this focus, undergo the least change of all others; as lime, chalk, and flint.

207. (12) All metals, exposed in an unglazed china-vessel, vitrify; provided the china be gradually heated, to prevent its breaking by too sudden a fire; and is likewise thick enough to prevent its fusing.

208. (13) If the matter to be tried by this fire, be exposed in a large glass-vessel, and the focus be carefully directed within the cavity of the vessel, so as to fall on the matter to be changed, but not on the glass; several extraordinary phenomena will arise therein.

209. (14) Nitre being put in such a vessel, and exposed after this manner, becomes wholly volatile in a moments time, and turns to volatile spirit of nitre: an effect the more extraordinary, in regard nitre, melted by any other fire, scarce changes at all, but runs like water: and to turn it to spirit by force of fire, there is always required a mixture of some terrestrial body, or the addition of true oil of vitriol, or the calx wherein the oil of vitriol still remains; whereas in the above experiment the business is done without any addition at all.

210. (15) The utmost light of the full moon collected by this glass, yields a most lucid focus, but no heat at all.

211. (16) It moves and agitates almost all bodies, even in *vacuo* itself, tho' often not without great danger.

212. From all which, and many other experiments, it appears that this focus made by M. *Tschirnhause*, is weaker than that of M. *Villette's*, and yet fitter for examining the nature of fire by its effects.

COROLLARY I.

*Dioptrical
fire in the
air.*

213. If the water, or shivers of ice in the atmosphere, be by any physical causes gather'd into vast globes of clouds, so as to form transparent bodies of a spherical figure, tho' they should only continue so the smallest space of time, yet being illumin'd by the sun at a semidiameter's distance from the hind part, they may in an instant produce a focus much more violent than that of *Tschirnhause's* glass, rarify the air in that place to a prodigious degree, and thus yield very sudden and extraordinary phenomena. If we reflect on the great clearness and purity of water raised into the atmosphere, and at the same time consider what a large quantity hereof is frequently poured down in rain in a short time, it will not be difficult to imagine, from the principles of dioptrics, what the effect must be of a huge sphere thus amassed. And if we further consider, that the rays in falling on such a sphere, and passing through the same, must produce an intense light and fire in the axis of the sun and sphere, behind the sphere itself; and

and that on the side illumin'd by the sun, there will no light, but a dense blackness appear, we shall be apt to conclude, that something of the like kind may be the case, when we find the heavens full of black clouds, which presently after burst into thunder and lightning. Another effect of this spherical form of clouds is, that the spaces intercepted between them differ exceedingly in their degree of light, or heat, from the spheres themselves; from whence again there must every moment arise strange varieties between the air, rarified and heated in one place, and condensed and cooled in another: which may be varying every moment. 'Tis enough to have mentioned these matters, which if carefully applied to meteors, will enable us to account readily for their appearances.

form

COROLLARY II.

214. Be pleased now to recollect what I before intimated, viz. that the mere attrition of flint against steel will make a greater and quicker change in bodies, and vitrify metals more readily than the greatest doubled focus of a burning-glass. This is apparent, in regard that *Villette's* speculum is much more powerful than *Tschirnhauser's* glass; and yet the collision of iron turns that metal into glass sooner than is done by the focus of that speculum: whence we have a new indication of the vast power of elastic solid bodies struck against each other.

Fire by collision quicker and stronger than the dioptrical.

COROLLARY III.

215. Hence we gather, that there is no need of any action of the sun hitherto known, in order to produce the greatest and most efficacious fire hitherto discovered; nor is there need of any inflammable matter or fuel to melt a metal, of all others the most difficult to fuse, in a moment's time, and this even in the coldest weather and place, without any melting furnace, or even without any vessel to contain the matter: all which paradoxes are confirmed by the common way of producing fire.

The sun not requisite to produce the intensest fire.

COROLLARY IV.

216. I have been in suspense some time, whether or no I might venture to publish an opinion, which has frequently employ'd my thoughts; and at length have determined to do it. It is probable, that in the action of fire observed among us, the sun does not emit any fiery matter, to which such action should be attributed; but that this luminary only has a power of directing the fire already existing in any place, into parallel right lines, from whence the same quantity of fire being again collected out of its parallelism by reflection or refraction, and united still closer, acquires new powers, and thus is enabled to produce all its effects. To illustrate this by an easy experiment; suppose a hollow brass cube, upwards of three inches square, and closed every way, except that one side being taken off, it is left open there; and suppose this cube directly opposed by its open side to the sun, only cover'd with a white paper; in the cavity of it apply M. *Fahrenheit's* tender thermometer, which consists of a movable spi-

The sun may emit no fire.

rit; while the paper prevents the sun'd rays from penetrating the cavity of the cube, and if the weather be cold, we shall find an intense cold in the whole vacant space of the cube; take away the paper at once, and at the moment that the cavity of the cube is illuminated by the sun, their immediately arises a considerable heat, which the thermometer indicates. Philosophers usually maintain, that the heat here admitted was sent from the sun's body, with a velocity scarce to be conceived; to me it rather appears, that the sun has only done now what it did before, and which it always does, *viz.* determine what we call fire into right lines, which can now reach the opake body without any obstacle, and thus drives the fire, which before, while the paper interposed, was equably diffused through the six containing squares; drives it, we say, without altering its quantity, in right lines against one side opposite to the open one, and thus heats the whole cavity, but especially such side; by merely directing the rays, and not by any increase of their number. Or suppose *M. Villette's* speculum to be directly opposed to the noon-day's sun, but covered over with a white veil, we shall have no more fire or heat produced in its cavity behind the veil, than at any where else; but at the instant you remove the veil, the fire, which before remain'd indetermin'd in the cavity of the speculum, is driven in parallel lines against the concave reflecting surface of the speculum; by which means that vehement fire is produced in its focus, and not, as usually imagined, projected from the sun: in effect, 'tis neither more nor less now than before, but only in a different direction: the same will hold in a refracting burning-glass; and thus neither the fire produced by collision, nor by a burning speculum, nor a glass lens, appears to owe any thing of its matter to the sun.

COROLLARY V.

*The physical
means of pro-
ducing the most
violent fire.*

217. From what has been observed, it appears, that the greatest fire which human art and industry is able to raise, is that where the focus's of *Villette's* speculum and *Tschirnhaus's* glass should meet directly in the same point: for as the focus of the speculum in the open air rises to 3 foot and an half distance from it in the axis of the speculum, we may, without hindering the action of the sun on the speculum, apply the burning-glass before it in the same axis of the sun and speculum, and in such dispositions, as that the focus of the glass exactly fall on the rising focus of the speculum: in the point of concurrence, therefore, between the two, we must have the fiercest fire, that any human means hitherto discover'd are able to produce. It must be own'd the action of such fire cannot be so commodiously determined upon objects, except in the very moment when they are applied in this focus; since the instant they melt, they will drop out of it. To conclude, if it be not contrary to nature to suppose spherical hollow icy clouds accommodated to each other in the air, after the manner above specified, what effects may not be produced thereby?

COROL

COROLLARY VI.

218. Suppose then the highest degree of fire present in such place; this must doubtless remain, as long as the axes of the sun, the burning-glass, and speculum, remain in the same right line, and their situations at the same distance; consequently, if the paths of the sun, the glass, and speculum, be continually kept in the same situation, this immense fire may be kept up, in a clear day in the summer-time, from nine in the morning to three in the afternoon; yet without requiring any thing like fuel to support it during the whole period: this gives us a very different idea of the highest degree of fire, from what has hitherto been conceived. It appears, in effect, that, by the laws above described, we may in any place of the universe produce a fire of any assignable degree of force and magnitude; and this durably and equably without the help of any fuel.

And of great continuance, without fuel.

COROLLARY VII.

219. The chief thing surprising in this fire is, that at the moment wherein its cause is produced by a due apparatus, it is found present in all its force, and thus immediately acts with the whole violence wherewith it will ever act hereafter. Another thing considerable is, that at the instant when this fire it exerting its utmost power, if the glass be but covered, the whole ceases at once, without the smallest sensible remains of it. But that light, heat, rarification, and all its other effects should perish so entirely, in so short a time, without leaving any thing in the place where they all obtain'd in so high a degree, must be hard to conceive. Yet the fire of the focus here described does not shew itself by any brightness, except just in the focus of the sun and speculum, nor yields any visible light on the sides thereof; consequently we have no indication of its presence by light, except the eye be placed in the axis, where the immense splendor would instantly destroy all sense of seeing.

Acting strongly in an instant.

COROLLARY VIII.

220. From a consideration hereof we discover that other wonderful property of fire, whereby, when alone, it is found to have a physical power of expanding itself equally from the centre of its mass, in a kind of radii, towards all parts; and as fire is every where the same, this power will also be every where the same: but when, on any account, this equality or balance of power is destroyed, stupendous effects must necessarily arise; and hence sometimes a wrong conceived opinion, that fire is then produced anew, or that its power in some way increased.

Hence a new notion of the nature of fire.

EXPERIMENT XVIII.

*That fire may
be united and
fix'd in bodies
for a time.*

221. True fire may be united with all solid bodies hitherto tried; and when once united therewith, adheres to them a considerable time, nor is found to perish or disappear in them instantaneously, as in the focus's above explain'd

222. Thus, if we try any of the ordinary bodies by committing them to any pure strong fire, they will be heated thereby to such a degree as to shine and melt: this appears from the experiments of *Tschirnhause*, *Homburg*, and *Hartsoeker*; nay, and those of all smiths, cooks, and other persons who use fire, and even from the whole earth itself, when illumin'd by the sun: in all which cases the same event of the experiment has uniformly been found; *e. gr.* in all fixed earths, stones, gems, glass, fixed salts, woods, minerals, and metals. To the same purpose is that observation of the great *Newton*, that water itself, if ever it could be converted into earth, might be so impregnated with fire as to shine; nor does there seem any thing more remarkable in this affair, than that there must be some other cause, beside fire, to connect fire, so long a time to these bodies; because the fire in the focus of *Villette's* speculum, how vehement soever, immediately perishes as the illumination ceases; and all those fires, before so closely united, separate and fly asunder. But if a ball of iron, a great circle of which is equal to that of the focus of the speculum, be held in it till thoroughly heated, the fire thus united to the ball will continue in it a considerable time, and exhibit all the marks of its being present; so that the fire which had been the focus, and would immediately have flown off, being thus received within the body, is retained there a long time, and hinder'd from being dissipated and extinguished. 'Tis hard to say what should be the cause hereof: if we answer that it is body; it may be asked again, in what manner this should retain fire; and whether in the place where the focus was before, there was nothing but fire alone, without any other body, even the air itself being expelled by the fire? Whether the reason of its vanishing so instantaneously is, that there was no body to retain it; whether the collected particles of fire, unless retained by some dense body, immediately return to their native equilibrium; and lastly, whether therefore there be no mutual attraction between the particles of the fire themselves, and whether, on the contrary, those particles do not mutually fly each other?

EXPERIMENT XIX.

*Yet remain
pure.*

223. This pure elementary fire, while thus united to bodies, is found every moment in every point of such bodies to have the real physical effects of fire.

224. For the principal characteristic of the presence of fire is discovered upon examining it by a thermometer; since, as we have already observed, if a
thermo-

thermometer be held at a certain distance from a piece of red-hot iron, for instance, the liquor in the tube immediately rarifies, and this continually, the nearer we approach it to the iron itself, and the less, the further it is withdrawn from it; nor does it matter on what side the thermometer be applied, provided the distance be the same: the fire therefore now residing in the iron, in as much as it acts on the thermometer, is the same true fire as before; and continues still in the same place, without any friction or parallelism, exhibiting all the effects of elementary fire. If we approach a sulphurous body to the same iron thus ignited, we shall find that as it comes nearer and nearer, it will begin to smoke, melt, sparkle, glitter, and catch flame.

225. The following experiment also deserves particular notice: having a quantity of the purest alcohol in a phial, and pouring slowly and carefully the minutest drop thereof on ignited iron, one would naturally expect that it should instantly be kindled; whereas, on the contrary, it no sooner falls upon the concave surface of the iron, than it gathers into a transparent globule like quicksilver, and runs like the same over the metal, without any sign of flame; and after in its progress it has arrived at a colder part of the iron, presently flies off in fume, without raising any fire. This appears strange, since sulphur, gunpowder, wood, and other bodies presently kindle, when laid in the same iron; while alcohol, which when gently heated kindles the quickest of almost all bodies, will endure this fire without kindling at all: a problem worthy some pains to solve.

EXPERIMENT XX.

226. It being found, then, that fire may be thus detain'd for so long a time, and to so great a degree in a solid body, it remains to enquire what the nature and conditions are of the thing which thus adheres; and as among the common properties found in bodies, weight is a principal one, I have endeavour'd to learn whether this fire adds any sensible weight to the fixed bodies it is in; and to this purpose made choice of such a body as would scarce lose any weight by a large fire, and which at the same time would admit and sustain a great fire for a long time; withal making use of a nice pair of scales, which would turn easily on their axis. Weighing then a parallelipiped of pure iron herein, I found it to weigh five *Amsterdam* pounds and eight ounces, while in its cold state; then exposing it in a large fire made of pit-coal, and further excited by blowing with a pair of bellows, till the iron was heated perfectly red on all sides, I then weighed it, after shaking off the dust, in the ballance as before; putting the former weight in the other scale, and still found it a just counterballance thereto; weighing exactly five pounds eight ounces as before: and leaving it in the scales till perfectly cold, for the space of twenty-four hours, I found upon weighing it again, that it retain'd precisely its weight, without either loss or gain in the whole course. The same I have also found in a large solid body of copper; which being tried with all the conditions above specified, the event proved

Without increasing weight.

proved the same. They who make these experiments will be apt at first sight to imagine they find the ignited body lighter than the cold one; the cause of which, on further examination, will be found owing to this, that the strings of the ballance, whereby the scales are fasten'd to the beam, are liable to be moist, and to dry again by the heat of the metal, which, when put into the scale to be weighed, raises some of the watery part into vapour, and makes that scale lighter of course; to prevent this, it may be expedient to make use of metalline chains instead of strings.

COROLLARY I.

*That fire is
loose and free,
both in heated
bodies and in
space.*

227. Fire, therefore, thus adhering to an ignited body, expands itself all around after the manner of an atmosphere; since from every point thereof we find its virtue diffused to a considerable distance, so as to produce all the effects belonging to fire; and in this law, that the nearer to the ignited body, the greater is the power still perceived: so that a globe being thus ignited, will form a heated sphere all around it, whose centre is the hottest of all.

COROLLARY II.

*But strongest
in the centre
of the heated
body.*

228. Hence we learn, that a great quantity of true fire is present in the body thus heated, and remains long in the same. For considering, that in these pieces of iron and copper, a great heat is produced to a considerable distance on all sides, which indicates fire to be present by these its distinguishing effects; and reflecting also, that during the whole time wherein this heat continues, the ambient cold of the air is every moment diminishing something of this heat; it will readily follow, that the quantity of fire in those bodies, when first ignited, must have been very great; and consequently, that in the whole mass thus heated, the quantity of fire is greatest in the body itself; greater we mean than in the adjacent air heated by it: and again, that if the body be long enough detain'd in the fire to be ignited, and penetrated by it through its whole substance, the heat will be greatest and densest in the centre of the body; which agrees with all observation.

COROLLARY III.

*And weaker
as it recedes
therefrom.*

229. From this centre towards the surface the fire is continually weakening, by reason the extreme surface is contiguous to the air, and thus receiving the cold hereof, is first brought to a state of coldness: the same also holds in the aerial atmosphere around it; those orbs whereof nearest the heated ball, will be hottest, and the exterior and remoter colder and colder to the outmost which is the limit of heat; beyond which the air is of the natural degree of coldness. From hence again we learn, that in the whole heated ball the centre expands itself most towards all sides, which is the nature of fire, as found greatest in the centre; but the next orb, being less expanded than the centre, will bound the expansion, and in some measure reflect and keep it again somewhat less hot, that is less expanded, and a little more

con-

contracted; and as this expansion and repulsion obtains among all the orbs which constitute the hot atmosphere, it appears, that during the whole time, wherein the fire produced in that sphere continues beyond what is found in the air not heated by this fire, there is a perpetual vibration and repercussion through the whole ball, in the body of it as well as in the ambient air; and that this vibration is considerably great and durable in proportion to the violence of the fire. Does not this vibration and repercussion produce a friction? Or does that friction produce fire, as in the manner of generating fire above explain'd?

Constant oscillation in heated bodies.

COROLLARY IV.

230. It were to be wished, that the proportional quantity of fire contained in such a body could be determined; but this is not so easy as at first sight may seem, by reason, though from the discovered effects of fire we may estimate its power, we cannot estimate its quantity; as the augmentation of the power of fire, arising from the nearness of its particles, is hitherto undetermined. For, so long as the proportion of the power of fire depending on its density or closeness, to that depending on the quantity thereof, is unknown, so long we shall be unable to argue from the effect of fire to the quantity thereof. The greatest caution can never hurt, especially in physical matters.

The quantity of fire hard to assign.

COROLLARY V.

231. Yet fire, while it thus remains in a heated body, does not seem to unite with it into one corporeal concrete mass; since, though greater than before, it is not found heavier; unless we suppose that fire thus growing to a body may add to its bulk, without increasing its weight. All we know is, that the extension of the heated mass remains greater, so long as the fire remains in it.

Fire does not concrete with body.

COROLLARY VI.

232. Neither does fire diminish any thing of the weight which the body would have at that time, and to which cold should restore it; nothing of this kind appears from any experiment yet made.

Nor makes it lighter.

COROLLARY VII.

233. Hence we are inclined to conceive this fire, *e. gr.* that diffused around a ball of red-hot iron, as a fluid, which exists every where both about and in the ball, and whose parts are all moved freely and indifferently therein; since if there were any determination in them to one part more than another, it seems a necessary consequence, that the body would rather be heavier, or lighter, when heated, than before.

But is indifferent as to weight.

COROL

COROLLARY VIII.

*The cause of
the detention
of fire in bo-
dies.*

234. Some cause there must also be which makes the fire continue so long in the heated body, and hinders it from flying away as soon as produced in it; since in the focus's of *M. Villette's* and *Tschirnhause's* instruments there are as strong, or even stronger fire than in our ball of iron; and yet that immediately and totally ceases, unless continually reproduced in the same place: so that fire cannot preserve itself in a place it has possessed, but needs something else different from it to retain it therein.

COROLLARY IX.

*Is the bulk of
the body.*

135. Whatever we can think of for this purpose, we find nothing to answer it except body itself, considered as distinguished from space, that is, as it resists and is impenetrable; and consequently is corporeal bulk. For we find, that if fire be imparted to bodies of different densities, they indeed receive the same degree of heat, but then they preserve this degree so much the longer, as they are denser, more ponderous, or have more corporeal substance: thus if several bodies of different weights be heated equally in boiling water, the heaviest will still remain hot the longest, and the lightest cool the soonest; and the rule holds almost universally, so far as experiments have hitherto been made. The vacuum in a *Torricellian* tube loses its heat the instant after it is generated: air heated in a pot quickly loses its heat; alcohol more slowly; water slower than alcohol; and quicksilver latest of all: so among solid bodies, wood, stone, and metals, if equally heated, retain their acquired heat the longer, in proportion as they are denser.

*And quantity
of fire.*

236. A greater degree of fire also vanishes later in bodies than a smaller; so that this also holds almost as an universal rule, that the greater heat a body has, or the more it is expanded by fire, till it arrive at the degree of fusion, the longer it retains the heat it has acquired. Thus if two bodies, in all other respects the same, be heated in different degrees, and the hotter have lost the degree of heat whereby it exceeded the less hot; the former will still remain as hot as the latter was at the first moment, and consequently will still require the whole time of cooling of the other to reduce it to the same temperature. It should indeed be examin'd, whether there be not some other cause to preserve fire when once produced, beside weight and the degree of heat: for if water and oil be equally heated, and the oil be lighter than water, most philosophers would expect that the oil, on account of its tenacity, would cool the slowest of the two; or that fire would continue longest in the oil. But upon taking two equal vessels, and filling one with water, and the other with oil of olives, and putting both in a larger vessel wherein I made water boil; and keeping both the other liquors therein, till I was sure they had each acquired the degree of heat of boiling water, I took them out, and set them in the open air, to see in what time they would both return to the same degree of coldness; the result was, that they did it in proportion to their weights.

237. Yet there appears some hidden cause, why fire, how great soever, can only give bodies a certain degree of heat; as we find in water, alcohol, oil, and quicksilver, when brought to the degree of boiling; yet as all do not boil equally soon, the lighter fluids may frequently admit a greater degree of heat and fire than the heavier, provided the former be not so easily brought to a state of boiling. Water is heavier than linseed oil, and when it boils is found to have 213 degrees of heat, beyond which the utmost fire cannot raise it; yet oil, though lighter, requires a greater or longer fire to make it boil, and when brought to this is found of almost 600 degrees of heat. The cause of which seems difficult to assign; since quicksilver, tho' fifteen times heavier than the same oil, only acquires the same degree of heat when arrived at ebullition: hence we find that there is something besides corporeal bulk, which disposes certain bodies to admit a much greater degree of fire than others.

Which may be greater in some particular bodies.

238. Hence it appears, why even hot water extinguishes a fire composed of a combustible mater; since it occasions the fuel to be surrounded with a less degree of fire than is necessary to its kindling; fuel never catching fire or burning with 213 degrees of heat.

Why water quenches fire.

239. Hence also a large fire will not melt a tin-vessel when full of water; since, in order to the fusion of that metal, a much greater degree of heat is necessary, than water will admit of; but if the same tin-vessel be filled with oil, and placed over the fire, it will soon melt, even before the liquor in it can boil. The same holds of lead with water in it under the same circumstance: from all which we may gather, that when fire has so disposed a body, as that it can act equably, and pass freely through the pores thereof, no more fire can be united to it; and this is found in fluids, at the time when they begin to boil; and in solids, at the time when in perfect fusion, so as to appear like a glittering boiling liquid; as we have found in metals, glass, salts, and all other bodies wherein the experiment has been tried.

Why water prevents tin from melting.

240. From this fertile head of observation we also learn, that fire has some connection with bodies; since the greater it is, the longer it adheres; and the denser the body, the longer it remains therein; that it adheres more largely to some bodies, especially oily ones, than others; that these heat more slowly, but imbibe a greater degree than others; that by how much bodies are heavier, the longer time they need to be equally heated with those that are rarer, by the same fire; lastly, that they require so much longer time to reduce them to the same temperature with rarer bodies, which cool quicker. All which things considered, we shall find many laws of nature settled with regard to fire, which will be of great use in physics. In effect, if this doctrine were carried to its height, we might be able by experiments to solve the following problems. *To fill a given space with such a body as will conceive any given degree of heat by the greatest fire: and again, to fill a given space with such a body as the greatest possible fire may be retained in it.* Whether iron, which melts more slowly than gold, be not, when melted, hotter, though lighter, than melted gold, may be worth enquiring.

Laws of nature with regard to fire.

COROLLARY X.

*Heat quickly
ceases upon ap-
plying a cold
dense body.*

241. Hence also, another law of nature seems to offer itself, *viz.* that bodies which contain fire more copiously than the ambient fluids, or other neighbouring bodies, lose it again so much the sooner, as the fluid into which they are immersed to cool is the denser. Thus suppose air, water, and quicksilver, in vessels exactly of the same temperature, suppose also three equal pieces of perfectly ignited iron, and let one of these be left in air of a known temperature, a second in water of the same degree of coldness with the air at that time, and the third in quicksilver of the same temperature with the air and water; the piece in the air will retain its heat a long time, that in water will lose it sooner, and that in the mercury soonest of all: in reality, it appears, that the iron in water cools so much the slower, as water is denser than air, that is about 800 times; and that in the quicksilver about 14 times sooner than the other in water. The workers in metals are well apprized of this, who to soften their metals, for certain purposes, ignite them thoroughly, and thus leave them in the summer-time, and in sultry weather, in the fire itself, till this gradually spending, sinks into cold ashes, and thus they are left to cool together: but when they require metals harder, for other purposes, they dip them suddenly in the coldest water in winter-time. We have therefore discovered two causes which accelerate the refrigeration of bodies, *viz.* the coldness and density of the fluids wherein they are immersed while hot. A third cause, which conduces to the same effect, is the agitating of the hot body throughout the fluid, which makes it cool still quicker; as by such means the body to be refrigerated is continually applied to a fresh quantity of the cold fluid. Hence, by the way, may be observed the physical cause of hardening iron; that metal, being ignited almost to fusion, is suddenly drawn through the coldest water, so as to be perfectly cool'd in a moment's time; by which means its particles, which had before been loosen'd and soften'd by the fire, become now intimately constringed and bound together; the effect whereof is, that they remain extremely close and hard, but at the same time brittle.

*Three causes
of cooling.*

COROLLARY XI.

*Why dense bo-
dies cool others
soonest.*

242. As to the reason why a denser fluid cools a hot body immersed in it so soon, it may be observed, that before the hot body was applied to the fluid, things remain'd equally cold, and consequently this effect could not arise from the diversity of cold, which cools one hot body immersed in it sooner than another; and may be suspected owing to this, that a denser mass of cold fluid draws more fire out of the hot body, in proportion to its density.

*The effect of
mixing hot
and cold li-
quors together.*

243. To determine which point I made the following experiment: Taking two equal quantities of the same fluid, *viz.* vinegar, alcohol, water, and oil, and reducing these to different degrees of heat, and then intimately mixing them together, they came to the same degree of heat, which was half the excess of the hotter quantity above the cooler, Thus, *e. gr.* mixing

mixing a pound of boiling water, which had 212 degrees of heat, with a pound of cold water, which had only 32 degrees of heat, the mixture will have 90, viz. half of 180, which expresses the difference between 212 and 32: from whence it appears, that the distribution of fire is here as the bulk; consequently that fire, by a close contact between the smallest particles of bodies of the same kind, immediately diffuses itself equally, and leaving its former body, lays hold of a new one; in which experiment there appears something very subtle, viz. that the common degree of heat is lost, and the excess distributed equally between the two masses. If we take quicksilver and water in the same precise quantities, but of different degrees of heat, and thus mix them together, a temperature will here likewise rise from the mixture, but with some considerable difference from the former.

244. For if the water were hotter than the mercury, when equal bulks thereof were mixed, the degree of heat arising from the mixture, was always more than the half which was expected. On the contrary, if the quicksilver were hotter than the water, and equal bulks of each were intermixed, the temperature produced by them was always less hot than the half of the differences. And this diversity was always found, as if in the former case three parts of hot water had been mixed with two parts of cold; or in the latter case, as if three parts of cold water had been mixed with two of hot: but when three equal bulks of mercury are taken, and two such bulks of water, it matters not whether you heat the mercury, or the water; since after mixtion the temperature will correspond to half the difference of the heat in each; as before in water, where equal portions were mixed. *And the difference.*

245. In this experiment it may be observed that we discover a new law of nature, viz. that fire is distributed in bodies in proportion to their bulk, or extension, and not of their density: for though the weight of quicksilver, with respect to water, be almost as 20 to 1, yet the power which produces heat proved the same in both, as if water alone has been mixed with an equal quantity of water. The same is confirmed from a multitude of other experiments, as we have intimated above, in making mention that all kinds of bodies, when committed a considerable time to the same common degree of warmth, never shewed any diversity in respect of heat, other than in proportion to the space they possess; so that nothing had been found in bodies which attracts fire; though the denser bodies are, the longer they detain the heat they have once conceived. The experiments here referred to were made for me by the celebrated *Fahrenheit*. What then shall we say is the cause why fire passes so much sooner out of its own body into another grosser, than into a lighter body, or even an empty space, into which it might penetrate with so much more seeming facility? *Fire resides in bodies in proportion to their bulk.*

COROLLARY XII.

246. Again, it seems to follow, that the greater a body is, the longer it will retain the heat it has once conceived, other circumstances being supposed equal; by reason the density of the extremity hinders the quick egress of the fire, which was endeavouring to depart out of the intimate parts thereof. *Large bodies detain heat long.*

of. Thus the orb nearest this confines another, and that a fourth, and thus to the end; so that a body thoroughly heated through its whole substance, always cools the latest towards its central parts: hence, as the magnitude of a body is still capable of further augmentation, it seems possible to have one so large, as that the heat once communicated to it, may persist during the longest period.

COROLLARY XIII.

Bodies of the least surface most retentive of heat.

247. It is demonstrated by geometricians, that bodies, *ceteris paribus*, have always the less external surface, by how much they are greater; from whence, again, it appears that large bodies retain the heat which they have once conceived the longest; consequently, that the more corporeal mass a body has under a lesser surface, the longer will it preserve its fire, compared to others.

Whence the spherical figure of the celestial bodies.

248. Again the same mathematicians shew, that a corporeal mass, while the same in quantity, can never be reduced under a less surface, than when form'd into a sphere; which figure therefore appears the most retentive of heat, both on account of the smallness of the surface, and of the equable accommodation of parts to the very centre, as well as their equable recess from the surface. And this perhaps is one reason of the spherical figure of the sun and fixed stars.

COROLLARY XIV.

Bodies divided cool the sooner.

249. But when a body, in other respects remaining the same, is reduced to a less bulk by dividing it, its surface continually increases, while its mass remains the same; and hence also it cools the quicker. A cube, divided into two equal parallelipeds, acquires $\frac{2}{3}$ more surface hereby; so a sphere, when divided into two hemispheres, acquires hereby two great circles of surface, and thus gains $\frac{2}{3}$ parts; and the sooner accordingly will they cool after heating. The division therefore of a hot body into lesser parts, and its reduction from a spherical figure to plain surfaces, are two causes whereby the cooling of bodies is greatly accelerated; as their contact with colder bodies is hereby much increased. Thus a pound of boiling water, while in a spherical figure, will retain its heat a long time; whereas if poured out on a large cold iron plate, it presently cools.

COROLLARY XV.

The different heats in men, whence.

250. From a due consideration of what has been delivered, we shall be able to see into the causes of the continuance of heat in other things. It has long been observed, that men of hard, firm, robust bodies, inur'd to exercise, and at the same time of dense, ponderous humours, are always hotter, and cool much slower than others; the cause whereof has been variously assigned: from the premises it follows, that such bodies, compressing strongly the dense fluids with their firm solids, must of necessity collect a great deal of fire, and retain it very tenaciously. So it has been observed that carcases, after the vital warmth has left them, cool slowly within-

within-side, and fast in the outer parts; the cause whereof easily follows from what has been said, without recurring to any vestal fire hid in the viscera of the body. On the contrary, that lax soft sluggish weak bodies can never acquire so much fire in their watery humours is clear, in regard the parts are always under a less attrition, less condensation, and diffuse into larger surfaces; by which means they are unfit, even to retain the heat which they have conceived. Hence may appear what mischiefs are to be apprehended, and what remedies to be applied in both cases: so universally useful is this doctrine.

COROLLARY XVI.

251. The theory of the cooling of bodies may be also applied to explain what has hitherto perplex'd the chemists, physicians, and philosophers; viz. whether human blood be hottest in the heart, and why? What a variety of opinions have been advanced on this question, which yet naturally solves itself on our principles? The blood is allow'd by all to be coldest in the veins; in its return from the external cold parts of the body, it becomes mixed with the new humours just taken into the body, and colder than the rest; it is also contained in loose, weak, unactive, large vessels, and thus returns to the right ventricle of the heart; whence the venous blood should, in no part of the body, be colder than in the right ventricle of the heart: but the excessive cold, which would thus arise, might endanger life itself; for which reason the blood, in its return by the veins to the heart, is still kept in a somewhat more temperate degree of warmth, by the heat which the arteries supply, and communicate to the body. And yet on these accounts the blood must still be coldest in the right ventricle, if compared with the arterial blood. But the same blood, thus cooled, is driven by the force of the right ventricle of the heart into the narrow strong elastic canals of the pulmonary artery; where being compressed and agitated with the whole effort of respiration, it is necessarily driven through one of the lobes of the lungs in equal quantity, as at the same time through the whole body, and all its parts. Hence, therefore, the blood undergoes more attrition, and consequently must conceive more heat in the lungs than in any other part; so that the heat would here grow intolerable, and even mortal, were it not that the air drawn into them by respiration, is always much colder than this blood. And *Malpighi* shews, that this blood in the lungs, being divided through a multitude of minute arteries, which every where accompany the smallest *vesiculae* of the lungs, is thus extended into an immense surface, and exposed to the air, which every moment receives an accession of fresh, and therefore cold air; on which accounts the blood again should not be colder in any part of the body than in the lungs. How wonderful the contrivance, that where for certain purposes the blood required to be hottest of all, should for others again require to be coldest! The new chyle and blood could hardly, without endangering life, be duly driven through all the vessels of the body, unless it were first attenuated and divided by a vehement attrition into its minutest elements; which again

Where the greatest heat in the human body.

The heat of the air in respiration.

could not be done, without at the same time producing an intense heat; yet if such heat had continued but for a small time, without the blood's being cool'd again from other causes, it must all presently have putrefied, and thus put an end to life by a most pestilent disease. I formerly observed in a sugar-baker's workhouse, that the air, in the apartment where they dry their sugar-loaves, is prodigiously hot and dry; so that I could not endure it for the smallest space of time, without danger of instant suffocation: this made me imagine I had found a proper opportunity of examining what heat of air living animals may endure. But being diverted herefrom by other necessary avocations, I desired M. *Fabrenheit*, and my kinsman *Jodoc. Provoost*, to make experiments with this view, and relate me the success: which being done with great faithfulness, I shall here rehearse; being of opinion that few experiments have been made, which conduce more to the understanding of the aerial fire, and its action on animal bodies, their humours, and parts; nor shall we easily find another experiment of more extensive use in chemistry.

The surprising effects of hot air upon animals.

252. This apartment then of the sugar-baker's workhouse was so hot, that the quicksilver thermometer being detain'd in it a considerable time, rose to 146. A sparrow, in a cage, being then placed in it at six in the evening, after remaining about a minute, gaped and panted with great labour, breathed thicker and thicker every moment, till its strength failing, it could no longer hold on its perch; but descending to the bottom, continued breathing very laboriously, and died in less than seven minutes. At the same time with the sparrow, a dog was shut into the same hot room, and, after continuing about seven minutes gaping, putting out his tongue, and panting for breath, sufficiently discovered how offensive the heat was to him; notwithstanding he kept in his wooden cage pretty quiet for about a quarter of an hour, when his breathing became very loud and forcible, and he struggled surprizingly to get away; but his strength soon after fail'd him, and he began to breathe slower and slower; but his respirations were still strong and laboured; at length these grew weaker and more languid; so that a little before his death they could scarce be heard: during the whole time he discharged an excessive quantity of foam, which was of a ruddy colour, and yielded so intolerable a stench, that none of the bystanders could bear it; and though so suddenly produced in the animal, was so horribly offensive, that a person coming near it, for the twinkling of an eye, fainted away, and needed to be recovered with spirit of wine and myrrh. The operator being thus struck, was disabled from applying the thermometer to the mouth of the dead animal, in order to learn what degree of heat his body had; but presently after his recovery, applying the thermometer, he found it at 110 degrees. With all this heat, and such violent struggles of the dog, there appear'd not the least sign of sweat on him. The dog when hung to the steelyard, weigh'd ten pounds.

253. While these experiments were making with the bird and dog, a cat was also put, in a wicker-case, into the same hot room; and, after continuing about a minute, began to throw herself upon the ground, pant, and in about a quarter of an hour breath'd loud with a hissing noise, and making

making incredible efforts to escape; after enduring like the former she died, cover'd with sweat as if drench'd in water.

254. By this we see how air, 48 degrees hotter than the blood of a healthy youth, found by applying the thermometer in his mouth, quickly raises a most acute disease, and causes death itself with all the signs of strong convulsions. What a change at the same time is made in all the humours of the body, which by this means become most fetidly putrid? There is not in nature a more abominable stench than this; which, though produced in so short time, in a sound animal, far surpasses any cadaverous matter; and could by its mere contagion strike down a strong person, inured to hard labour, and bring him to the very brink of death. How must the humours have been resolved, and how chang'd from their natural state, when the saliva itself could in so short a time assume a red colour? Fire alone could not have done this; for the flesh of a dead animal being suspended in the same heat, only grew dryer, without resolving into such a noisome filth; but the vital motion, while it remain'd in these animals, produced a further degree of heat by its attrition in the lungs, and at the same time a tendency to putrefaction; and as nothing was brought in to temper and allay it, rose to a much greater degree than in the hot room itself. Hence the oils, salts, and spirits of these animals became perfectly putrefied in about 28 minutes time; and the bird only lived about one minute in this state. Yet the servants employed in the sugar-house can enter the room when thus heated, and continue in it a short time; taking care to quit it seasonably for refreshment. Thus at those iron-forges, where the run metal is cut into large iron plates, the workmen can endure the heat for a moment, but unless they retire speedily, and recover themselves by lying down, and breathing a colder air, they soon fall and faint away. When the air is heated, by art, to the same degree as it is found in a healthy person, a man placed in it will find it intolerably hot and stifling, so that he cannot long endure it; but endeavours by all possible means to cool himself, and must otherwise quickly faint away. Thus hot air weakens our strength, and cold restores it; and unless the heat be temper'd with alternate cold both plants and animals soon perish.

255. Hence we learn, that the heat of the blood, both in the veins, arteries, heart, lungs, and other parts, is pretty equable; that it is made the hottest, and also the coldest in the lungs, and thus between the two reduced to a proper temperature.

C O R O L L A R Y XVII.

256. By how much therefore the matter whereof a body consists is denser, its bulk greater, and its figure more exactly spherical, the more disposed it is to preserve the fire it has conceived, for a long time; which is every where confirm'd by experience; and if to all this, the space wherein the body is found be exceedingly rare, or next to a vacuum, we shall have all the physical causes hitherto discover'd, which concur to the long preservation of heat.

What is required to make bodies most tenacious of heat.

C O R O L L A R Y

COROLLARY XVIII.

Yet these grow cool in the air.

256. Yet bodies ignited even to a degree next to fusion, however large, solid, and spherical they may be, soon return in air, to the temperature thereof.

COROLLARY XIX.

Whether vibration be the cause of heat.

257. May we not, therefore, after Sir Isaac Newton, lay down the vibration of the particles which compose a body, for the sole entire cause to which the continuance of fire is owing in a heated body? 'Tis certain a large bell, with a single stroke given in one single place, by a metalline elastic body, will yield sonorous tremors, sufficiently audible for several seconds, and continue the same, though not so as to be heard, a considerable time longer; as may be learnt from sprinkling sand on the bell: but otherwise the vibrations, even of elastic bodies, quickly cease among us.

EXPERIMENT XXI.

Dense bodies heat slowly.

258. By how much bodies, whether fluid, or solid, are denser, the longer time they require to conceive an equal heat by the same fire.

259. Suppose a hollow paralleliped of brass, open a-top, and full of water, and on this suppose placed several equal cylindrical vessels, filled to the same height with fluids of different weights, and let fire be put under the whole, that the water in the paralleliped may be equally heated; the effect will be, that the lightest and rarest fluids will soonest expand, and the densest the latest: the like will also be found, if thermometers be placed on the same. Air heats the soonest, then alcohol, then the purest petrol, then oil of turpentine, then fair water, then salt-water, then the strongest lixivium, metals, mercury, and gold.

COROLLARY I.

The disposition of body to heat.

260. The mass or mater of a body, therefore, both admits and dismisses fire with difficulty; so that body, considered as body, appears tenacious and retentive of its temperament, and resists any change to be made therein.

EXPERIMENT XXII.

Small bodies heat sooner than great.

261. Bodies, *ceteris paribus*, grow warm slower, by how much they are larger; and quicker, by how much they are less: this is so well known from many vulgar experiments, that it may be laid down as an axiom.

EXPERIMENT XXIII.

262. By how much bodies are denser, and at the same time larger, the more and longer fire they require to arrive at their greatest heat; as also the nearer they are brought to a spherical figure, or a figure which contains the most matter under the least surface. Thus, suppose a pound of iron form'd into a thin paralleliped plate, and another pound cast into a spherical form, immerse the two in boiling water, the plate will acquire the heat of the water presently, the sphere more slowly; so that thus far the surface appears to be the measure of the heat and cold, both admitted and let go again.

What bodies heat the slowest.

EXPERIMENT XXIV.

263. Among all the bodies hitherto observed, there is none which spontaneously, and when left to itself, becomes hotter than all others. This, how paradoxical soever it may appear, is the result of induction; for we have shewn in the above-mentioned experiments, that all those which are reputed the hottest bodies, if they be left to cool in an air of the same temperature, always return to the same degree of heat and cold. Thus the phosphorus of urine, when immersed in water, becomes as cold as the water which surrounds it; though upon admitting the air, it immediately grow hot. The phosphorus prepared of alum and unctuous matters calcin'd, while kept in a glass phial, has the same temperature with the phial itself, nor makes any change therein; but upon giving free ingress to the air, it presently catches fire. Linseed oil, which in the greatest natural cold never congeals into a solid mass, but still remains fluid, is yet then equally cold with the coldest ice: nor is the purest spirit of wine any hotter than quicksilver. That wonderful spirit of nitre, first discover'd by *Glauber* and reputed fiery in the highest degree; or that oil distill'd from saffrafras wood, when kept at rest in cold vessels, are equally cold before their mixtion, as the most rigid ice; though after mixtion they appear to constitute an intense fire. Flint and steel in frosty weather, however cold when at rest, yet by a single collision instantly produce a vehement fire in the cold atmosphere; so that as far as bodies have hitherto been tried, there is no known one which of itself is more disposed to heat than to cold; or which of its own accord grows hotter than any others. And yet the contrary opinion is deeply rivetted in the minds of men, who imagine that at least the bodies of animals are always hotter than other things; which indeed may be granted, if we consider them as alive, while the vital attrition of their parts is continually collecting fire, and gathering heat; but when the healthiest man is drowned in water, all things still remaining the same, except that the motion of attrition is wanting, the carcass soon returns to the degree of coldness of the water. It may be objected, that dead carcasses

No one body naturally hotter than others.

are sometimes found very warm a considerable time after death, which seems to argue, that the bodies of some animals maintain a heat within themselves; but let it be considered that in such cases, there is a putrefaction, or a continual and brisk motion, which by its attrition collects the fire, otherwise foreign to it. So cold hay, if pressed into close heaps, and thus moisten'd, will produce a vehement heat, and sometimes break out into flame. In effect, fermentation, putrefaction, effervescence, and mixtion, often produce the most intense heat; as will be shewn more expressly hereafter; but these motions never obtain in any one simple body, and consequently are not proper, or spontaneous in any body. Other difficulties, which may be started against this doctrine, you will easily solve.

COROLLARY I.

*The cause of
heat, and of
its continu-
ance.*

264. Does not a dense body, therefore, the hotter and hotter it gradually grows, contain the greater quantity of fire in it; and is not this greater quantity of fire, thus procured, owing to the greater quantity of fire applied and united to such body; and does not the long application of the same fire occasion a greater quantity of it to be united with such body?

COROLLARY II.

265. Is not the physical cause of fire continuing so long in a body once heated, owing to the fire itself, which insinuates so plentifully, and continues so long in the heated body?

COROLLARY III.

266. Or is it the matter of the heated body, and the fire communicated to it, that conspire together to produce this effect?

SCHOLIUM.

*Conclusion of
the doctrine of
elementary
fire.*

267. Hitherto we have endeavoured, by a few simple experiments, to explain the chief points which we have been able to discover concerning the nature of what philosophers call elementary fire; by considering it as it is created, and exists in nature, separate from all other created bodies. And we have further also considered it, as it remains pure in bodies themselves, without taking any pabulum from them, but remaining pure, and only driven into parallel or converging rays: and again have considered it as collected in bodies by motion and attrition alone. No pains have been spared to explain and inculcate this doctrine fully, before proceeding to the consideration of fire, as supported by combustible matter, which is very different from the former, both in its nature and effects. Many errors have arose among the chemists, for want of distinguishing, with sufficient accuracy, between these two kinds of things, which are known by the common name of fire. We proceed now to examine vulgar fire, which many hold as the only fire; but, by the way, it may be proper to subjoin some circumstances relating to the history of fire, as given by other authors; that the present history

history may be render'd as complete as possible, and all the inventors find their due praise.

268. An iron rod, a foot long, being heated red-hot, became $\frac{1}{60}$ longer than before: and a glass cylinder, a fathom long, under the same circumstance, gain'd $\frac{1}{50}$ in length (y). A metalline ring thus heated gain'd $\frac{2}{100}$ in its diameter (z). A glass globe became extended $\frac{1}{1000}$ part by the meer heat of the hand applied on its surface (a).

The discoveries of others upon the subject.

269. A thermometer, when placed in a hot fluid, at first sinks, but presently rises again; and if set in a cold one, first rises, and then sinks (b). This is shewn to be owing to the expansion or contraction of the glass on the first application (c). Fire, in heating fluids, does not seem to expand them equably, but *per saltus*, or by certain fits (d). Mercury, being put in a glass phial, and this in water, and fire under both, till the water boils, the mercury rises equably; but after the water has once boil'd, will rise no further, though a much greater fire be applied: and hence excellent thermometers may be made of mercury (e).—These matters I thought proper to insert, after the authors here-mentioned, to give further room for speculation; since one thing may frequently correct another. If you take two cold metalline rods of equal weight, heat one of them red-hot, and then examine them by the ballance, the hot one will be the lightest; and if a coal be laid under the cold one, they will return to an equilibrium. Two metalline rods being hung in *equilibrio*, if a coal be laid over the one, it will become the lighter, or if laid under it heavier (f).

(y) Sturm. Col. Part. II. p. 101.

(z) Saggi di Natur. Sperienf. p. 182.

(a) Amontons Mem. Acad. R. 1704. p. 12.

1705. p. 4.

(b) Saggi di Nat. Sper. p. 178, to 181.

(c) Ibid.

(d) Halley Transact. Abridg. Tom. 2. p. 234.

(e) Id. ibid.

(f) Saggi di Nat. Sper. 266.



Of Fewel, or the Pabulum of Fire.

Two ways of 1.
fire residing in
bodies.

HAVING shewn that fire remains always the same, without alteration either in its nature or quantity; and that it may be collected in certain bodies, *e. gr.* gold and silver, and remain a considerable time therein without causing any sensible destruction of them; it remains to examine those bodies wherein fire may be preserved the longest time; but with this condition, that while retained, and sometimes also increased therein, the bodies themselves are consumed and dissipated by the action thereof, so as almost to disappear from our notice; for the fire once collected in them usually continues, and retains its active nature, till those parts of the bodies, wherein it was before supported, be dissipated by the fire; and when those parts are thus dissipated, the fire itself usually disappears, nor can maintain its power long after, in the remains of such body.

The proper
meaning of
fewel or pa-
bulum, as it
relates to fire.

2. Wherefore, as both the fire, and the body disappears at the same time, those bodies, or the parts thereof wherein it was found, have acquired the popular appellation of *pabula*, or *aliments* of fire; which, with this limitation, is allowable. But if to the word *pabulum*, we affix the precise idea of a matter feeding fire, and converted by the same into the very substance of elementary fire; and which laying aside its former nature, assumes that of fire just created, we make a conclusion, which before it be admitted as true, deserves mature consideration; and which, however easy to be asserted, will be very difficult to prove. In effect, from this doctrine it must necessarily follow, that the quantity of bodies which are thus employed to feed and sustain fire, as being continually wasting or diminishing, and the quantity of elementary fire in the universe being increased in proportion, by which means fire still growing, and all other bodies wasting, we should by this time have had nothing left but fire: and yet by comparing the most ancient times with our own, there appears not the least indication of such increase of fire. On the contrary, it is generally observed, that the power of fire, and consequently the quantity of it, remains much the same, without any considerable increase, and no diminution. Of this we have a proof from those ingenious and accurate meteorological tables, made many years ago by that excellent geometrician *Nichol. Cruquius*, which shew a great equability in the degree of heat. So after the burning of huge forests, which has sometimes lasted several months, the least addition of heat has never been observed to remain. Might we not expect, that during almost 6000 years, wherein the whole combustible matter of the inhabitable part of the earth has been so often burnt, the heat, by such continual augmentation, must have at length become too fierce for tender plants and animals to endure; whereas in reality the heat has still continued the same in every quarter of the globe. A certain determinate warmth of the air and soil is always necessary to cherish the tender embryo's of plants, hidden in their seeds, to fill, and distend them with moisture, and thus open their weak subtile *stamina*. A heat beyond the proper limit burns up the originally almost fluid little organical

nical body at its first appearance; or if the heat be too remiss, the embryo droops and perishes as certainly. The like holds of animals, whose male seeds insinuating into the *ova* of the females, require so temperate a warmth, that the hundredth degree on *Fahrenheit's* thermometer burns and destroys them; and they can hardly be brought to perfection in the seventieth degree of the same. So the impregnated *ova* of insects, which will endure the severest winter's frost, are, however, soon destroyed by a degree of warmth a little more intense than ordinary. Thus if we pursue our enquiry throughout all nature, we shall manifestly find, that fire continues the same as ever; nor after so many unhappy conflagrations caused by meteors, so many eruptions of burning mountains, so many fires in kitchens, stoves, and furnaces; so much fire and desolation in war by the accension of gunpowder, do we find any augmentation of fire at this day: we may add, that by the following examination of the pabulum of fire, it will plainly appear, that the case is much otherwise than is usually imagined. — We proceed therefore to the consideration of this useful and agreeable point; and in the first place, laying down that there is a combustible matter found in vegetable, animal, and fossil bodies, we will, to proceed the more distinctly, next consider this matter as found in the vegetable class; since by this animals are also fed and sustain'd; and we find this class easier to examine than that of fossils.

3. All known vegetables are capable of burning, and in so doing of feeding *Vegetable* fire, the larch-tree not excepted; but as these may either be exposed to the *fire* crude, and in the condition they were in when alive, and full of fresh juice, or as dead and dried, it will be proper to consider them in both those states; and because when we are acquainted with the green kind, what belongs to the dry will be easily understood, our first enquiry shall be what it is that is properly combustible in green or living plants.

4. All crude vegetables, of what sort soever, contain water, a fine substance called spirit, consisting of invisible volatile particles, usually odorous, which ordinarily reside in the water, and when separated therefrom, dissipate in the air; also an acid volatile salt, which usually appears in a fluid form, an alkaline volatile salt, a very light volatile oil, and usually strongly impregnated with the peculiar smell of the plant, a more fixed and ponderous oil, a black coal, which being agitated by a strong durable fire in a close vessel, remains fixed and black; white ashes which remain from this coal after burning it with an open fire; a salt left in these ashes, which being extracted from them by lotion, is of a fixed alkaline nature; and lastly pure earth, as it is called, the remains of the ashes after the salt is extracted. — This is an accurate enumeration of the several matters discoverable in a burnt vegetable; and among these, as changed by the various actions of fire, we must enquire which it is, that is properly inflammable or combustible in respect of fire.

5. If we suppose then a crude vegetable, with all the above-mention'd parts in it, committed to the fire, while they are yet moist, it will first yield a smoke or vapour, which rises from the plant in form of a cloud, and according to the conditions of the subject may be collected either in form of

of an acid or alkaline water, which usually carries its specific smell along with it; and this vapour is very thin, light, and almost pellucid.

6. When the plant is deprived of this first part in the fire, and therefore begins to dry, another fume begins to arise, which is usually black, much thicker, opaque, dense, acrimonious, fetid, and grows every minute more and more gross, dense, and at length almost pitchy, and comes out whirling about the vegetable.

7. Soon after this arises a bright shining crackling flame, in lieu of the smoke, which ends where the flame begins; so that there is always the less smoke, in proportion to the greater clearness of the flame; and if the flame be again extinguish'd, the smoke appears thick and black as before; if such smoke, however fluid and volatile, be collected into a mass, it forms a black, unctuous, tenacious, fetid, bitter pigment, called soot.

8. The vegetable, thus consumed to smoke, flame, and soot, leaves another part behind, which may be ignited like a metal, but is utterly unfit for maintaining fire, and is called ashes. These ashes are various, according to the species of the vegetable burnt; thus, if it abounded in volatile, acrimonious, saline, alkaline, fumes, the ashes will be almost insipid, as we find in garlic, onions, scurvy-grass, rocket, hedge-mustard, cresses, leek, water-mint, mustard-seed, treacle-mustard, and the like pungent anti-scorbutic plants; where the fire hardly produces any fixed salt. On the contrary, if the plants be acid and succulent, much salt will remain in the ashes; as we find in the green woods of most trees, which being laid, in large blocks, on the fire, distil a great quantity of acid water at the ends. Lastly, if the plants be austere, acid, or aromatic and bitter, their ashes will yield the greatest plenty of salt.

9. If a vegetable, moderately dried by exhaling its water, yet not too old and sapless, be exposed to the fire, the same things will ensue, and, in the same order; only the first watery fumes will be less than in the former case.

10. Lastly, if a vegetable, when rotten, fungous, light, dry, and old, be laid on the fire, it will not burn with so fierce a flame; but will ignite and shine for a little while, and soon fall into ashes, which have scarce any salt in them: and it will afford very little smoke or soot.

11. And as all these things are observed in the burning of every vegetable, we may hence make some inference concerning the matter in them which properly burns.

*The water of
vegetables.*

12. First then, let us consider the water, which makes a considerable part in all vegetables to be burnt; this, it is true, will admit a certain quantity of fire, and retain it for some time; but this fire only rises to about 212 degrees, before it affects the particles of the water, and their situation, with regard to each other, in such manner, as that they will admit or retain no more fire. Thus no art is yet known, whereby we might impregnate the particles of water, so as to give them a fiery brightness, and consequently make them yield a shining smoke: far from this, if water whether hot or cold be thrown in a quantity on flame, or any burning matter, it immediately reduces such fire from the degree it before had, to its own degree of

212, and consequently puts an end to all burning, takes away ignition, extinguishes flame, and dissipates the glittering brightness of fire: and when water is resolved by means of a violent fire into an active vapour, which diffuses itself briskly all around; yet being thus reduced into the form of fume, it exhibits all the same effects in respect of fire; as may appear by this, that if a live coal, or a burning torch be put in the thick steam of hot water, it will be as perfectly extinguish'd, as if water had been cast on it. So it appears by chemical distillations, that water, however agitated by fire, still remains pure water as before; yet it cannot be denied, that water has a great effect in the burning of vegetables, which would hardly happen were the water away. For if water be poured on boiling oil, we find a new action arise between the water, fire, and oil, very different from what would otherwise have obtain'd. Suppose, a pound of oil boiling hot and flaming in a copper vessel, the fire in this oil will be about 600 degrees, and not be very violent, if the oil be kept stirring; throw an ounce of water at once into this boiling burning oil, and it will produce a violent noise of the parts, with a strange unequal motion through the whole; for the water cast on the hot oil, in falling into the pores thereof, by its weight, meets continually with a degree of heat, almost triple to that which the hottest water is capable of; by which means the particles of water being dilated with an incredible force, and agitated by a vehement motion, shake all the tenacious parts of the oil, dissipate and dispel them into air: if therefore in burning, water and oil happen to meet, a new and very different fire arises from them, to which the smiths are no strangers; who when they would raise a fierce fire, by blowing up their coals with the bellows, first sprinkle them with cold water. Nor must it be omitted, that a greater heat may be communicated to water, when the weight of the atmosphere being increased, it is more compressed thereby: and in effect this augmentation is so considerable, that for every increase of the weight, a sensible addition is perceived to the degree of the heat. If therefore in burning, the water should be compressed as with a double weight of the atmosphere, its power of disposition would be terrible. From the consideration of this, I have often wonder'd at the immense height to which the heat of water might be raised by fire, if there were any water in the centre of the earth. By the law demonstrated by *Mariotte*, it appears, that air, at the depth of 409640 fathoms under the surface of the earth, would be as heavy as gold. Supposing this law to obtain every where, how much greater weight than must water be there compressed with; with how much greater force would fire there burn; and would not water, if there heated to the degree of boiling, shine like ignited metals (g)? Besides this, we find another extraordinary power of water on fire; for if a fixed alkaline salt be fused with a strong fire in a crucible, till it run like water, and thus be expeditiously poured into an iron or brass vessel; *e. gr.* a mortar, at the bottom whereof is a small quantity of water, the salt will fly from it with incredible force, as the chemists have often found to their great loss and danger. But nothing is more terrible than the power of water, applied to the fire found in melted copper; for if in a copper-foundery,

(g) See *Hist. Acad. R.* 1703. 6. and *Mem.* p. 101.

foundery, where the melted metal is contain'd in large vessels, the smallest quantity of water, by misfortune fall on it, a clap like thunder with horrible force is immediately produced, which throws down every thing. So if a few grains of melted copper be thrown into water, a shock immediately ensues, which bursts the strongest vessel, both at the bottom and sides, converting it almost into powder (*b*). Hence may appear what effect the water naturally contain'd in a burning vegetable may have, in respect of the fire burning such vegetable, if we consider it as only a water; and how much its power may be still increased, if there be any oily, saline, or other metalline parts therein: so that a body, which otherwise is thought proper for subduing the force of fire, may, under some circumstances, prove the instrument of heightning and increasing it beyond belief.

*The native
spirits of ve-
getables.*

13. We proceed now to examine the spirits of vegetables, which swim and float in and with water, in the natural state of things; or without any previous fermentation. These, however pure and well cleansed of water we may endeavour to procure them, yet we never find any thing in them to sustain flame or fire: on the contrary, when well purified, if we cast them on fire, they presently extinguish it, provided there be no oil in them. Thus if green rosemary be so treated, as to exhale its fragrant water, we shall find nothing inflammable in it; and if by a gentle fire we continue further to separate the odorous part from the other, in close vessels neither will this be found fit to maintain fire, but on the contrary will put it out.

*The volatile
acid salts.*

14. We come next to consider that part by chemists called acid salts, which exhale with the water and odoriferous spirit above-mention'd.

15. It has long ago been observed, that these volatile acid salts often prove highly acid, as appears from the smoke raised in the burning of acid woods, and also the acid soot sometimes collected from them: and in distilling the heavier woods, as box, juniper, gualacum, oak, and the like, the spirits obtain'd are almost as acid as vinegar itself; the shavings of gualacum distill'd in a clean vessel, with a moderate fire, yield a liquor which has all the marks of a thorough acid; and this, as I have often observed, being carefully separated from all its adhering oil, which may easily be done by filtration, and a slow distillation, becomes exceedingly acid, liquid as water, and considerably volatile: yet after all this purification, if it be cast on the fire or flame, it does not increase, but extinguish them. That other pure and vegetable spirit, procured by fire from the native balsams of plants, has the same effect. If we distil some pounds of the purest turpentine, in a clean vessel; with a fire gradually raised, this oily fat balsamic substance will yield a limpid liquor, intimately miscible with water, and of an acid taste; which is perhaps one of the noblest diuretics known: yet this too, if cast on fire, puts it out like common water. From all which it appears, that the acid volatile salt, found in burnt vegetables, is not fit for the maintenance of fire or flame, but rather destroys them.

16. It may be objected, that sulphur is made of the fossil acid of vitriol, alum, or pyrites, with a vegetable, or fossil oil. Whence it seems to follow, that

(*b*) See *Hist. Acad. R.* 1699. p. 110.

that the latent acid in this sulphur, affords a pabulum for fire: but it may be consider'd, that the oil alone here affords such pabulum; and that the acid flies unchang'd out of the flame, in form of fume, which does not stay in the flame once kindled, but trickling down in drops, returns again the same genuine acid, under the new denomination of oil or spirit of sulphur *per campanam*.

17. We now come to examine volatile alkaline salts, which exhale from *Volatile alkaline salts.* most vegetables in burning, and may be collected in form of foot, and may even be procured from some plants by distillation; as from garlick, onions, scurvy-grass, rocket, hedge-mustard, cresses, leek, radish, mustard-seed, treacle-mustard, and the like: if the salts thus produced, be carefully separated from the water, spirits, and acid salts, they will be found utterly unfit for burning, and not at all inflammable in the fire, but either fly swiftly away, or diminish the briskness of the fire. Neither does that volatile alkaline salt procur'd from a vegetable, by first putrefying it, though obtain'd in greater plenty, or stronger than the former, appear in the least fitter for the sustenance of fire. But this to be understood of these salts, when reduced to such a degree of purity, as that no oily part adheres to them; for in distillation as well as in burning, the volatile saline alkaline part, rising upwards, carries with it the fetid oil, which is also volatile and closely united with the former; whence we may sometimes be deceived; because the same salt, with this oil adhering to it, if cast on the fire, will truly burn; but when, by the method we shall hereafter explain, the oil is all perfectly separated, and the salt left pure, its inflammability entirely ceases.

18. Oil, which is produced from vegetables by distillation, commonly *Essential oils.* known by the name of essential oil, appears the most volatile of all oils procured from them; and at the same time the most genuine, as being less adulterated with foreign matters than the rest. If this oil be exposed, in a clean vessel, to the fire, and then be kindled by the application of flame, it will burn away, and smoke but little; leaving behind a few black, funguous, friable, carbonaceous earthy fæces: and if this oil, however pure it is usually reputed, be again distill'd from boiling water, it becomes much purer, thinner, and lighter than before; leaving behind a great quantity of new fæces, which will not rise. The oil thus purified, or as the chemists call it rectified, being again exposed to the fire as before, will kindle, and in burning yield less smoke, and leave less fæces than before; and the fæces remaining after the second distillation will be much less combustible than the former. From this experiment it appears, that though the inflammable matter be here diminished, yet what remains is become more inflammable; and still fitter and fitter for the maintenance of fire. If then we continue this purification of the oil, by repeating its distillation from water, a great quantity of oil, before thought to be inflammable, will now be found of a terrestrial nature, and unfit to burn in the fire; and the other oil, which again rises in the distillation, being thus further separated from the incombustible fæces, becomes every time lighter, thinner, and more limpid; burns clearer in the fire,

fire, yields less smoke, and leaves less fæces behind it; till at length, after repeating the operation a multitude of times, the oil becomes exceedingly subtil, scarce yields any smoke, and burns away without leaving any fæces and yet this last and purest oil, which appears wholly inflammable, if distill'd over again in a clean glass retort, by a gentle fire, gradually rais'd, and this be repeated a second time, the greatest part of it, as we are inform'd by Mr. Boyle, will turn into earthy fæces, remaining at the bottom, and scarce combustible; the oil itself at every new distillation growing still purer and more inflammable, so as to burn away without leaving any sensible fæces, or yielding any smoke. If then all the fæces, obtain by the repeated distillations be collected together, and burnt in a clean open vessel, in the open air, they will ignite, sparkle, and yield a smoak, and sometimes also a flame, and at length fall into ashes utterly incombustible. Whence it appears how little a part it is, even in the purest oil, that truly burns, or turns into flame, exclusive of the smoke and ashes; which will be a considerable point gain'd in the history of fire, consider'd as it acts on its fuel, and is acted on, and changed by the same.

*Oil extin-
guishing fire
and flame.*

19. Hence we proceed to a new experiment. Take a live coal full of fire, put it in a copper-vessel, and pour on it some cold ætherial oil of turpentine, which is held the most inflammable of all oils; and to our great surprize it will put out the coal of fire, with a smoke and hissing, as certainly and readily as if water had been poured on it; so that cold oil is not kindled by fire after the manner usually imagined, but require certain conditions in the application of the oil to the fire. It will be imagined, that flame is necessary to this kindling of oil, let us therefore make the trial.

20. Place a lighted candle in a vessel, in such manner as that the extremity of the flame may be below the brim; then pour the former pure distill'd oil of turpentine into the vessel, and as it rises up to the flame, we shall find it extinguish the same, without the oil catching fire: and if the same oil be heated in another vessel till it smoak, and be ready to boil, and while in this state we throw in a small live coal, we do not still find the oil kindle, but instead thereof the coal sinks dead and hissing to the bottom. And again, if we plunge a lighted candle in the same heated oil, instead of giving fire to that, it becomes extinguish'd itself.

*Empyreumatic
oils.*

21. It remains to try those other vegetable oils, procured by distillation in dry vessels, without the addition of water, having the empyreumatic smell, and being thicker and more opaque. These, if treated after the manner above-mention'd of distill'd oils, exhibit the very same appearances. At first they flame, yield a black copious smoke, and leave a great quantity of fæces; but by repeating the distillation, become still purer, lighter, more limpid, and inflammable, afford less smoke, and leave less fæces; and when purify'd still further, burn still more perfectly; thus being by art reduced to a kind of essential oils. As all these things therefore obtain in all oils of vegetables, after what manner soever they exist therein, whether by a native concretion in other parts, or by a natural secretion in those of gum, balsam, rosin, pitch, or by distillation, or lastly by burning;

ing; we have hence a view of the true nature of the combustible matter, and may draw several conclusions belonging to the history of fire: for want of which, great mistakes have been committed both about the nature of fire and fuel.

22. All vegetables, when burnt so far as to be ignited from their surface *Charcoal.* to the middle of their body, but not wasted to ashes, and being then suddenly extinguish'd in water, or smother'd by excluding the air, or burying them deep under ashes, or other bodies, lose their fire, and are converted into a thoroughly black body, called coal, or charcoal; and if any vegetable body be put in a retort, and urged with so violent a fire, so long continued, as that nothing more will rise out of the retort into the receiver, the whole being done in close vessels without any access of the air; upon letting all cool again, we shall find at the bottom of the retort a black vegetable matter, which is also a true coal, and in all respects like the former. Either of these, when very dry, being laid on the fire, presently catch, and retain it strongly, till consum'd almost wholly, without yielding smoke, so long as any blackness remains; though during the whole time it yield an exhalation, which if received in a close place, quickly and insensibly destroys any animal: and this holds whatever the operation be perform'd on, herbs, wood, bituminous turf, or peat. After all the black part of the coal has been thus consum'd, what remains is a whitish dust, called ashes; on which the fire, however applied, will have no further effect. All we can do is to unite fire with them, as we do with metals, stones, and the like bodies, which retain fire without wasting. It is most remarkable, that this unfitness in coal for sustaining fire, commences at the same time; that its blackness gives way to the cineritious or ash colour, and continues as long as the blackness remains; as may be shewn by a familiar experiment in a slender kind of coal, *viz.* paper burnt to blackness: for if a spark be caught on paper thus burnt to blackness, it will run this way and that, still deserting the parts as they appear cineritious, and shifting to others where the blackness yet continues; which, when it has consumed, it immediately quits, and takes possession of some neighbouring part yet black; till having consumed every part of that colour, it leaves the paper only a slender compages of white ashes. Vegetable coal therefore is that part of the plant, from whence the fire has expell'd the water, spirits, volatile salts, and some part of the lighter oil, less intimately mixed with the rest; leaving behind the earth, fix'd salt, and gross oil, which being rarified, attenuated, and reduced to a black colour by burning, is diffused over the increased surface of the earth and fix'd salt: for all that appears black in coal is the mere oily part, which being rapidly moved in the first action of the fire, and hereby greatly extended, freed, and as it were extricated from the unflammable parts; and being of a nature nearest a-kin to flame, it is attracted to the surface of the body, and, by the stifling of the fire, remains spread on the outer face thereof, where, before the substance was chang'd to coal, there resided water, spirits, and volatile salts. From the whole we may infer, that the combustibility of coal consists altogether in its oil, which remains in it; and that

that the other parts are incapable of ignition, or inflammation, so as, after the manner of a fewel, to consume by the fire they receive.

Ashes.
The salt and
earth whereof
no pabulum of
fire.

23. Not to omit any thing belonging to this history, we proceed to examine the ashes of vegetables perfectly burnt: These, if produced from a mere vegetable, are of a white colour, and a saltish taste, a few instances only excepted; and when boil'd with fair water, in a clean vessel, yield a lixivium of an acrimonious, alkaline, fiery, urinous taste: and if the operation be again repeated, and the water a top be poured off the ashes, and fresh water poured on them, boil'd with them, and poured off again, till at length the water comes off as insipid as it was poured on; and lastly, if all these lixiviums be mixed together, and evaporated to dryness, there will remain, at the bottom of the vessel, a white, sharp, alkaline, fiery, fix'd salt, which being made red-hot with a vehement fire, may retain the fiery brightness some time, but is by no means fit to feed fire, kindle a flame, or burn away; so that fix'd alkaline salts appears as incombustible as stones, &c.

24. And if that part of the ashes, which remain'd at the bottom of the water after the separation of this salt, be carefully dried, and well preserved from all admixture of other matter, it will be found a light, white, simple earth, unalterable by fire: whence the assayers make their tests of this mix'd with fair water; and if continued in the fiercest fire, for the longest time, it will keep red-hot like other incombustible bodies, but never burn, flame, or turn to the nutriment of fire.

Smoke.

25. We begin now to perceive what part of the vegetable that properly is, which in a common fire made of vegetable matters, feeds such fire and flame; and what those are which remain so long in the burning fire: but while this proceeds, a thick smoke arises from every part of the kindled fire, which at first is watery and thin, but grows every moment thicker and blacker, and most so, when the flame is ready to start forth; which usually happens with some crackling noise: upon this eruption of the flame, the smoke instantly diminishes, and the more as the flame is quicker and brighter; so that when this is in its utmost brightness, the smoke seems to cease entirely, tho' some still continues. Hence smoke seems only a confused mass of different parts of the vegetable fewel, rapidly moved by the force of fire, and thereby carried upwards, and continually driven against each other, tho' not yet kindled to a compleat ignition, but when, by the continuance and increase of this force, those parts become agitated by a stronger fire applied to them in the air, they grow red-hot, and thus of smoke commence flame; the parts of the smoke, by such attenuation, appearing perfectly fiery. Hence also appears why flame playing over the whole burning surface, seems to consume all the lower parts, agitated by the fire, in mere flame without smoke; it being certain that all but the watery part of smoke may be wholly converted into flame. This was long ago discovered by an elegant experiment of the fire consuming smoke, wherein the eye plainly sees, that the black smoke raised by fire from vegetables, is itself a kind of coal, combustible in a strong fire, or a violent flame; for the smoke here falls into mere

A volatile
coal.

ashes,

ashes, or becomes so attenuated in its substance, as to escape our senses, and vanish into air.

26. The inventor of this simple instrument was M. *Dalesme*, an ingenious engineer of *Paris*, in the year 1686 (i). The ingenious Mr. *Justel* first exhibited the figure of it in the philosophical Transactions, about the same time. It may be conceived from what follows: ABCD is a cylinder, made of hammer'd iron, hollow, and open at both ends, to whose lower base BD, is fitted on the inside a small cylindrical kind of grate BD, which serves for the fire-place of the instrument, being so fitted to the cylindrical tube EFG, as that the cavity of the one corresponds to that of the other; both are made of the same capacity, and of the same matter, and in the same manner; the tube ABCD, being open at G, and shut at E. If then the tube EFG be first well heated, and live coals be laid on the grate BD, and other combustible fuel on these, the flame produced hereby will descend into the tube EF, and proceed through FG, and all the heat issue at the orifice G; the smoke also produced thereby will all take the same course, and pass through the tube EFG, through the middle of the flame which fills the whole cavity thereof; by which means, being acted on by the fire through its whole progress, it loses the grossness and other properties of smoke, and turns into flame; in form whereof it issues at G, and vanishes without any apparent smoke or soot. M. *De la Hire* has added some notes and observations to the account of this machine (k).

A fire made to burn its own smoke.

See Plate IV. Fig. I.

27. And not to be wanting in my endeavours, I have contrived an engine something to the same purpose. ABCDEF is a vessel made of five equal plates of hammer'd iron carefully solder'd together, only the uppermost left open at ABCD; at the depth of EI within the vessel is a grate IKLM, and on the side DF is an elliptic aperture NO, of the breadth of MK, and the height of EI, to which is lastly fitted the tube OGH, open at ON and H, and every where of the same width.——If then we place burning coals on the grate LK, till the vessel is hot, the air in the aperture of the tube NOGP, will heat at the same time; and again laying coals against the part of the tube NP with the same view, no sooner will the air under the grate and in the tube NOGP be heated, but the heat before found in the vessel CK, over the grate, produced by the coals, will begin to diminish, and proportionably thereto the heat in LF under the grate, and in the tube NOPG will be increased; whence it appears, that the power of the fire and flame is driven downward, which produces a cold over the coals on the heart.——The instrument being thus prepared, suppose a quantity of straw laid on the coals when kindled, the flame will fly rapidly downwards, darting under the grate, and at length driving through the tube OGH, issue without smoke at H, where it produces an intense heat, at the same time that the space CK is quite cold.

See Plate IV. Fig. II.

28. The like will be found, when, instead of straw we place wood, turf, sulphurs, or oils: and so powerfully is the fire driven thro' this tube that

(i) See the *Jour. des Sav.* of that year, p. 116.

(k) See the place above cited in the *Jour. des Savants*.

that it will grow red-hot, and the fire make a raging noise. It is further observable, that bodies, which in burning usually yield either a very fetid or a fragrant scent when laid on the fire, here yield not the least smell at all, but consume away without the least sign thereof; only leaving the ashes at the bottom of the vessel under the grate. The other parts are all impell'd by the atmosphere, gravitating on the aperture of the fire-place, into the other deeper and narrower tube; so that all the fire and flame here is found in the space LFOGH.

29. Hence all the combustible parts of the fuel, turn'd by force of fire in to the thickest smoke, are now driven into this pure flame, and not into the open air; by which means the parts of the smoke are agitated with the utmost violence within the fire; whereby in so long a passage, and so fierce a fire, they become so attenuated, that all before combustible in them, which is capable of being attenuated, becomes utterly insensible, and dissipates without leaving any marks of their peculiar natures. Smoke, then, appears to be a combustible matter violently agitated, but not yet brought to shine or ignite; and flame is the same matter at length perfectly ignited and divided into its smallest particles.

30. This inflammability of smoke may be shewn by other experiments: for if the shavings of guaiacum be distill'd, with a vehement heat in a retort, there will appear a thick smoke; and at the end of the operation, when only an attenuated and rarified oil rises, if this smoke be made to transpire through crannies in the luting, and a candle be applied thereto: it will catch fire, not without some danger: and the same may hold of any part of an animal. Thus smoke appears near a-kin to flame, and the blacker it is so much the nearer, in regard it then becomes a true thin attenuated coal, extremely volatile, and easy to be kindled, as may appear from the preceding history of coal: so that the oil in this smoke is the only pabulum it affords to fire, as will appear more clearly hereafter.

Soot.

31. Lastly, in the burning of a combustible matter, the smoke rising on high, and sticking on the sides of the chimney, penetrates the same with a black unctuous moist substance, which gathers on the surface in form of a black fleece, or wool, very light, and easily swept off, called soot; which is itself a volatile coal, but of an unctuous kind, and, when dry, very inflammable. It is extremely bitter, like other burnt oils; fat, by reason of the abundance of oil in it; and black, like all coals, on account of the burnt oil diffused over it. This matter, however simple it appear, when carefully analysed by a chemical distillation, yields first a great quantity of water, which, when collected by itself, extinguishes fire and flame; and the watery vapour itself exhaling in this first distillation does also readily put out fire; so that it can hardly be properly called a spirit: After this comes a quantity of a yellow inflammable oil, which affords a plentiful nutriment to fire and flame; the more subtile part of this oil, called by the name of spirit, is also inflammable: after this it affords a very volatile salt, then another less volatile, and at length a dryer one; from all which, if we carefully separate the oil and spirit just mentioned, there will be nothing in-

inflammable found; but a mere incombustible salt, as above intimated. The last thing in this analysis will be coal; which has been already sufficiently consider'd.

32. Hence we see what soot is, and wherein its combustible part resides. If a quantity of this, gather'd fresh and dry from the chimney, be laid on the fire, it will burn vehemently, and break into an open flame, almost as much as any other combustible matter, as men have often found to their cost: A chimney, under which great store of combustible matter has long been burning, and which for want of sweeping is become thick lined with soot, is, upon making a larger fire than ordinary under it, apt to catch fire, which bursting out a top, frequently occasions great damage.

33. From the whole it appears, what the proper inflammable part of a crude vegetable is; and that oil, in whatever form it existed, whether thick, or thin like a spirit, is the only pabulum of fire. *Conclusion of crude vegetable fewel.* *form*

34. By what has been above said, we find that there is nothing in crude vegetables, at the same time capable of dissolving in water, and yet of feeding or sustaining fire.—If we proceed to consider those vegetable matters, which are produced by a chemical fermentation, from plants disposed to admit such fermentation, we shall find that called wine the capital one. This liquor, when duly refin'd, and brought to the purest state, yet, if cast on the fire, presently extinguishes it; nor can ever be brought to burn, or made fit for the maintenance of flame: and if the wine thus examined, be again committed, in a pure glass vessel, to a moderate fire, the most volatile part of it will gently rise in form of a smoke, which, upon applying a flame to it will scarce burn, but rather puts the flame out. *Wine not lighted by fire.*

35. But if this vapour be cooled and collected into a liquor, and heated as before, it will afford a new fluid, which will mix with water, and also burn with fire, yielding a plentiful flame, and consuming wholly therein: for the vegetable matter which remains of the wine, whether it be its fæces, or what stays behind after the above-mention'd distillation, if it be tried with fire, will yield much the same substances, as we have above shewn to be produced from a crude vegetable. From which instance it appears, that fermentation produces a vegetable moisture miscible with water, and fit for the sustenance of fire; which was not before found in the crude plant. *But spirit of wine easily.*

36. We proceed now to consider vegetables, as treated in another manner. If crude vegetables, while full of their native juice, be laid in large heaps, or stow'd in large wooden vessels, and there kept close and well press'd, they will spontaneously conceive heat, emit watery fumes, a rank smell, and at length thick smoke, flame, and sparks: whereas if the same vegetables, after gathering, be dried in the air, and then heaped up as before, they will remain without alteration; but if in this state they be again well moisten'd by pouring water on them, they will be disposed, as before, to gather heat and fire; and if after long continuing hot in this manner, without any flame ensuing, they grow cool again, we shall find them *Putrefied vegetables take fire.*

them perfectly putrefied, and turn'd to a fetid pulp; which being distill'd, will first yield a watry vapour, which puts out fire and flame; and if the remainder be tried and burnt by an open fire, it will yield much the same as the former, either crude or fermented vegetables, produced by burning.

37. Lastly, if vegetables, when perfectly putrefied, be slowly distill'd with a moderate fire, in a glass retort, till they are left almost dry, the first matter that rises will be a fetid unctuous turbid water, containing a volatile alkaline salt dissolved therein, procurable by art in its proper form; the unctuousness of the water being rather owing to this than to an admixture of true oil. For whether we cast this liquor into the fire, or separate the compound fluid into a purer water, and its proper salt, and thus cast both separately into the fire, the event will be the same, and the fire be equally extinguished in both cases.

*And certain
inflammable
parts.*

38. If the putrefied matter, after separating this first liquor, be put almost dry in a retort, and the remainder be urged by a stronger fire, there will first arise a thin fluid unctuous matter, which swims in water, stinks, and feeds flame like oil, or spirit of wine. After this spirit or thin oil is thus separated, if the fire be raised still further, a volatile alkaline salt and a thicker oil will arise together, in considerable quantity; and as this oil is still found inflammable, so the salt still remains incombustible. Lastly, if what remains after the preceding separations, be urged for a long time, by a still stronger fire, it will yield another thicker, and almost pitchy oil, and which is found very combustible: and at the same time with this, there will arise a thick vapour, which on the application of a burning candle readily catches fire in the open air. After all, if the fire be still kept up in its highest degree, a phosphorus will be produced; and this out of a vegetable, though not in so solid a form as that from the parts of animals; yet in other properties near a-kin to it. After the phosphorus nothing remains of the vegetable matter but a black coal at the bottom of the vessel, such as that above described; wherein a black inflammable oil predominates, and no fix'd salt can be found.

*Conclusion of
whatever is
combustible in
vegetables.*

39. From all which we may safely pronounce concerning the parts of plants, both of those which spontaneously, on the application of fire, will catch flame, and consume therein, and withal continue or sustain the fire in that place for some time; and of those which by any art may be procured from them, capable of producing the same effect, so that among these parts, water, native spirits, all salts and earths of plants are disposed to be heated by fire; and consequently would admit fire within them; and when admitted, retain and preserve it a considerable time, with the limitations above express'd; and by their means the fire also, which they have conceived, may be communicated at pleasure to other bodies: also the fix'd salts and earths of such vegetables are capable of being ignited by a strong fire, and of preserving their redness for some time, but no one of these four parts is any way capable of being turn'd to flame, or consumed by it; as is necessary to a proper pabulum of fire; and the oils of plants, of what kind soever they be, also their balsams, gums, and resins, and the gummo-

gummo-resins arising from a mixture hereof, are all five capable of being heated by fire, of retaining the fire a considerable time, of communicating it to others, even without ignition or inflammation, but by a further fire they will melt, boil, and feed fire and flame; yet this their inflammation only reaches to that part of them which is oily; the other parts in them, being chiefly earthy, undergo the same as above-mention'd.

40. Lastly, vegetable spirits produced by fermentation, oil left in fermented bodies, or extracted therefrom, spirits also and oil produced by putrefaction, all of them consider'd as pure spirits, or oils of such kinds, are every where absolutely inflammable: from whence again it appears by undeniable experiments, that the oils of vegetables, of whatever kind they be, are the only matter in them capable, without the addition of any other parts, of being agitated by the fire, so as to produce true flame; and when once produced, preserve it as long as the oily part lasts: and in the mean while they are sensibly consum'd by this flame, till at length they disappear, and the flame cease at the same time. And tho' this oil exist in vegetables after very different manners, and may be chang'd by very different causes, yet while it remains oil, it still continues inflammable, in the sense above explain'd: and as fermentation and putrefaction attenuate this oil to such a degree as to turn it into a subtil spirit, capable of mixing with water; yet such spirits still remain inflammable, and have the effects before specify'd concerning true oils, as the pabulum of fire. And further, whenever all that part, which has the character of a true oil, is perfectly separated from any vegetable compound, or the several parts thereof; what remains is not capable, by any art or means hitherto discover'd, of being brought into a condition to conceive or nourish flame: yet the watery spirituous saline and terrestrial parts, while they contain those oils, are violently agitated and moved by the fire in kindling of the oil, and thus increase the force of the fire by their vehement agitation amongst the fire, and produce a great attrition in the flame itself, by the agitation of their parts (m). Hence also those parts thus agitated, communicate the fire with much

(m) One great effect of the matter of light, diffus'd among terrestrial bodies is, according to the younger *Lemery*, that being detained, and mix'd along with certain compositions of salt, earth, and water, it therewith forms oils, fats, and in a word all inflammable matters, which are only such in virtue of the particles of fire they contain. What principally inclines us to this opinion, is, that in the analysis such bodies are reduced into salt, earth, water, and a certain fine subtil matter which passes through the closest vessels; so that what pains soever the artist uses not to lose any thing, he still finds a considerable diminution of weight.

'Tis certain that salt, earth, and water, whether united together, or separated, never

* *Mem. de l'Acad. an. 1713.*

become inflammable; but even hinder or retard flame, in bodies that are inflammable. It may even be advanced, that these principles are of no use in the composition of inflammable bodies, but to detain and arrest the particles of fire, which are the real and only matter of flame; and which only rises into the air under this form, when the inflammable body having been expos'd to some external fire, has had its cells of vesiculæ broken up, and the contained fire set at liberty. It appears, therefore, to be the matter of flame that the artist loses in decomposing inflammable bodies*.

M. Homberg indeed contends, that sulphur or oil is fire itself; or that there is no sulphur besides fire. In the analysis of oils,

much greater force to other bodies, and also defend the oils for some time, and prevent their being too quickly consumed by the flame, and thus hinder the fuel from being wasted too soon.

41. From all which effects duly consider'd, it appears, that the power of vegetable fire does not only depend on the mere elementary fire, and the oil kindled by it, but more especially on those other incombustible parts agitated, with great vehemence, within the sphere of activity of the fire. Hence elementary fire acting on the purest of all combustibles, *viz.* highly rectify'd spirit of wine, does not produce such violent effects, nor so intense a heat, as when it acts on heavy pit-coal, the greatest part of which is unflammable. So the unctuous wood of the pine-tree affords a stronger fire, than the purest oil when carefully purged of all unflammable matter; and hence also this paradox, that inflammable matter alone, with pure fire alone, often affords a less fire, than inflammable mixed with unflammable matter. For this end the author of things has no where created any pure inflammable body; but has every where hid it within the veins of other incombustible bodies, that it might hereby produce the stronger effects. This being a matter of great importance, will require to be thoroughly understood. Supposed then an unctuous wood laid on an open fire, the mere mixture of its oil with the fire will produce a flame, which playing over the surface of the wood, kindles, consumes, and converts into new flame all the oily part it can touch; by which means the first flame is not only kept alive, but continually increased; so long as this oil meets the active force of the flame: in the mean while, the salt and earth still closely cohere with the oil to be burnt, and become divided into minute parts by the rapidity of the kindled oil, and are agitated in the oil more than the parts of the oil itself; thus undergoing a prodigious attrition, the quickest of any we can well conceive; which violent attrition of those hard parts so strongly compress'd by the atmosphere, draws the fire to those places, and thus renders it much hotter and more copious than before: which increase of fire in its turn still further agitates the oil; so that from the whole 'tis easy to conceive the force of a fire thus kindled. While this passes, the solid body of the wood laid on the fire grows hot through its whole substance, and by degrees rarifies, dispels the elastic parts with great vehemence, and pours out its melted oil, and by such successive action continues the fire. Lastly, if it be consider'd that pure oil alone burns in the fire, it will follow, that the oily tenacious

says that author, their whole substance becomes reduced into a deal of aqueous matter, some insipid earth, and a little salt, partly volatile and partly fixed; the real principle sulphur, which connected these several ingredients together, to make an oil, being lost in the operation. The same befalls the sulphur, in all bodies whatever, that undergo a rigorous analysis; so that we have no positive way of arriving at the knowledge of its nature by the decomposing of mixt bodies: hence he was led to examine it, by making artificial mixts or compositions. And the re-

sult, he assures us of a great number of operations, of this kind, gave him plain indications, that 'tis fire is the principle sulphur, and that this is the only active matter in all bodies.

To support this opinion, he endeavours to shew that fire, or the matter of light, is always in motion and action; and that this matter may be introduced into the other principles, change their figure and augment their weight and bulk, and connect them together, so as to produce all the mixts which fall under our observation. *Mem. de l'Acad. an. 1705.*

cious soft parts thereof are swiftly agitated every way by the particles of fire, but do not produce so much attrition, nor of consequence so strong a fire: indeed they burn quicker, but then their flame is more short-lived, and does not act so fiercely.

42. Having said thus much concerning vegetable fuel, it remains to consider the action of nature; while this matter being committed to the fire feeds the flame.

43. I have been at great pains with this view; and in the course of my enquiry find first, that all those parts of vegetables, which are capable of fire of making a true flame, are easily miscible among each other, whenever they are pure, simple, and inflammable. Thus alcohol, which is the only known body perfectly inflammable, however prepared, provided it be pure, may be intimately mixed with any other alcohol prepared in any other manner, without the least alteration thence arising. So also all pure oils, when rightly purged of other parts, will mix thoroughly with each other, as appears from all instances; though there are some oils prepared from semi-fossil matters, as amber, and the like, which by a long distillation yield a sort of oils which lie in separate strata over each other, without mixing together; but then it is to be observed, that these ponderous oils, forced over by the ultimate force of fire, contain much of the mass of the body itself, liquified and mixed with them. Besides, we are here only speaking of vegetable oils, with regard to which it may be said universally, that they are all of such a nature, as to be easily miscible into a liquid concrete, uniformly similar. Again, all the purest oils, and alcohol itself, may be so accurately mix'd together, as to form one homogeneous fluid, in which even the best microscope shall not discern the least diversity of parts; which however is to be understood with this restriction, that there be not the smallest drop of water in such oil or alcohol, otherwise so intimate a mixture will not be made. So also camphor, which may be reckon'd among the vegetable solids, burns wholly away, dissolves and mixes intimately, not only in alcohol, but in any pure oil: and the like holds of other perfectly inflammable vegetables, which mix in oils or alcohol the more thoroughly, as they are more entirely inflammable: the same hold of resins, balsams, and gummy-resins, which, when mixed under the conditions above specify'd, may be liquify'd even by a small degree of heat, or even run spontaneously. Thus, how easily does camphor melt, as also balsams, colophonies, and rosins? 'Tis certain many of these inflammable bodies are incapable of being frozen by any degree of cold hitherto known; as appears in linseed oil, and others. Nor must it be omitted, that all these perfectly inflammable bodies, whether they be pure or mixed together, contain certain viscid parts which produce a brisk cohesion, and make a considerable resistance to their separation. Thus if we consider alcohol, the most subtle of all known fluids, we find, the parts even of this run into a kind of veins or spires, which have an apparent lentor or cohesion. So in mixing pure alcohol with water, we even then find the parts of the alcohol tending to cohere, and shooting like little eels between the water: so if an oil be diluted with alcohol, the like *striae* are found, which is a proof of their cohesion. Add, that all the oils,

How fire is supported by its pabulum.

which are held inflammable, burn so much the quicker, the more perfectly, produce less smoke, and leave fewer ashes, the less thickness they have; and the nearer they approach to the tenuity and subtilty of alcohol: but at the same time the flame will be so much the weaker, as these oils are the thinner.

44. Having said thus much concerning the nature of the pabulum of fire, we proceed to shew the manner wherein fire acts on this pabulum, and the reaction of the pabulum itself on fire: and to this purpose we shall exhibit some further experiments.

E X P E R I M E N T I.

*Flame and
fire quench'd
by alcohol.*

45. Putting some pure cold alcohol, which is the most inflammable of all known fluids, in a clean cylindrical brass vessel, and then plunging flaming brimstone-match therein, one would expect that the alcohol should thence catch flame, instead of which the match itself is immediately extinguish'd, as entirely as if it had been plung'd in cold water. But what is still more extraordinary, if we take a live burning sparkling coal out of the fire, and immerge it expeditiously in the alcohol, this likewise will be extinguish'd as readily as if it had been thrown into water. But if the former sulphur-match be of sufficient length for the tip of it to enter below the surface of the fluid, and yet some of the fiery part still remain above it, the alcohol will then catch fire, and the flame presently spread over the whole surface.

C O R O L L A R Y I.

46. Hence it appears, that the most inflammable of all bodies can only catch fire on its outermost surface contiguous to the air; and that fire, if immerged in the body of the inflammable matter, so as to leave no lighted part above such surface in the air, is so far from kindling the inflammable body, that itself becomes extinguished.

C O R O L L A R Y II.

47. It is false, therefore, that fire can easily kindle even those bodies which are most inflammable.

E X P E R I M E N T II.

*The preserva-
tion of fire and
flame by al-
cohol.*

48. Filling the same vessel again with pure alcohol, and heating the same to such degree as to make it smoke, approach a lighted candle to the fumes arising from the hot alcohol, the result will be, that the flame of the candle no sooner comes in contact with those fumes, than they catch fire, which soon spreads over the whole surface of the liquor; but still the flame thus conceived confines itself strictly to the superficial parts, as a limit beyond which it cannot pass; nor can it, by any art, be brought to turn any of the alcohol

alcohol below the surface into flame; but the bulk of the alcohol still remains entire, transparent, unignited, under the flaming surface; nor is at all consumed, except so far as some of the spirituous parts separated from the rest, and carried upwards by the heat, arrive at the surface of the alcohol contiguous to the air, where they are presently kindled. In effect, 'tis impossible to set any on fire except such as have risen so as to float in the air, as may be fully shewn. For if cold alcohol be kindled slowly on its surface by the application of a sulphurous body after the manner above indicated, *viz.* so as that part of the lighted body remain above the surface of the alcohol, while the rest is plunged into the body of it: only a small weak flame will be excited thereby; but when the alcohol is first heated, and emits its spirituous parts into the air through the surface, the flame it then catches is greater and more violent; as more parts, being thus emitted into the air, are capable of being turn'd to flame. Thus in the present vessel, the same alcohol still yields a more copious flame, the more it is heated thro' its whole substance; and consequently, when heated so as to boil, it will yield the strongest flame of all. So if a vessel full of boiling alcohol exhale its spirituous parts into the air, and those be confined within some narrow sphere, and a person approach such sphere with a lighted candle; the whole place will instantly catch a live flame, and shine with a weak momentary light, which presently tends to the surface of the vessel; and as soon as arrived at the same, covers it, and prevents any more spirits being emitted into the open air, forcing it all to be acted on and changed by the incumbent flame, which becomes a while supported thereby, but changes it into a matter which is no longer alcohol. Again, this flame persists in the vessel so long as the least drop of alcohol is left in it, and then goes out; whence it appears, that the whole alcohol cannot possibly be consumed by the flame in one instant, but only the superficial part of it, which was contiguous to the air; consequently the wider such surface, the sooner will the consumption be effected: on which principle this consumption may be accelerated and increased at pleasure: so that we have two known ways of accelerating the flame of alcohol, and consequently its consumption, *viz.* by heating it with fire, and spreading it into a larger surface. Add, that alcohol thus wholly consumed by burning, leaves no fæces behind it; and, if pure will not so much as stain the place where fired; nor does the eye perceive any smoke on the surface of its flame; and if a clean white paper be laid over the flame, it will contract no filth or soot, but only a clean moisture; tho' the sense of smelling is a little affected with the fragrantcy of the alcohol. This flame of kindled alcohol, when in a still air, rises in to a conical figure, in regard the fire being the greatest towards the centre, heaves up the incumbent air strongest there; and the fire being less confined towards the circumference of its base, becomes weaker of course, and less able to lift up the air. The flame appears blue to the eye; though, when carefully observed, we find it of various colours; the basis being always blue, and the vertex double, the inner always appears yellow, and the outer blue. What is most wonderful in this experiment is, that if we cast a live coal into this alcohol thus burning, it is immediately extinguish'd, nor can retain its fire in or under the alcohol;

the

the cause of which must be, that a live coal requires a much greater degree of fire than that in the boiling alcohol to keep it burning, whilst the alcohol will not admit of any greater degree of heat than is communicated to it by boiling. Thus the hotter coal, when in the alcohol, which is colder, loses the higher degree of heat which was required to keep it in a state of ignition, and therefore extinguishes or declines to about 180 degrees of heat, about which it was that the alcohol began to boil; but which is too weak to kindle any combustible matter, that is, to produce a shining fire in its oil: and since the coal being wholly immersed in the alcohol is thus excluded from any commerce with the external air; hence neither can this kindle the alcohol, but only by its first access occasion a greater motion, and make it displace more of its spirits upwards; and thus, as we have already mentioned, make an increase of flame at the time. But if the coal were so laid on the burning alcohol, as that some of its ignited part should remain above the surface of the alcohol, it would then burn strongly with the alcohol itself.

EXPERIMENT III.

Pure flame
examin'd
See Plate IV.
Fig. III.

49. I have long thought about a method of finding, by experiment, the manner wherein fire acts on its pabulum; and at length have hit on the following one. Having a cylindrical brass vessel full of pure heated alcohol, I set it on fire, and placing the vessel, while on flame, upon a table, in a still place, put a large glass vessel over it, being a receiver of the figure of a cucurbit, whose bottom is carefully cut out, so that it becomes a true bell; the upper part, where it is narrowest, being open so as to admit the little finger, while the lower, which is ten inches in diameter, is open throughout. This clear transparent bell being thus placed over the burning alcohol, we plainly see all the phenomena related of the burning alcohol in the former experiment.

Affords a pure
limpid va-
pour.

50. First then, it is observable, that the whole surface of the bell becomes darken'd by means of the flame burning within, so long as the bell remains cold; but after this begins to heat by the flame, it begins at the same time to turn transparent again, and when quite hot, is perfectly so. If now we view the whole space within the bell, there appears not the least sign of any visible fumes, but the air remains entirely clear through the whole bell; and the vessel of alcohol being cylindrical, the flame, so far as we can observe, continues equable from beginning to end: at length we find *striae* form'd within at the bottom of the bell, as usually happens in spirits, in the action of distillation.

Or water.

51. Yet these are not the true spirits of alcohol, since we find their taste utterly watery; but to be better convinced of this, we need only apply a lighted candle to the thin fume which ascends through the upper orifice; if this were the vapour of alcohol, it would immediately catch fire; instead of which, it here extinguishes the flame of the candle, much the same as the vapour of water would do. If this candle, lighted as before, be put under

the glass vessel, and held some time in the space filled with the vapour of the lighted alcohol, it still remains ignited, and burns till it be consumed; but does not in the least kindle the vapour of the alcohol, which, if it had retain'd its former nature after passing thro' the fire, it necessarily would have done. It appears, then, that the most inflammable matter of all bodies, when turn'd into flame by fire, and consequently while it truly feeds such fire, is changed into another matter, which, after this change, is unable any longer to feed the fire, but turns, so far as we can judge, into a kind of water. And here it may be asked, did this water exist before in the alcohol, and was it only separable by these means? Or does fire, by burning the alcohol, convert it, by an intrinsic change, into pure water? Or did the air supply this water during the time of conflagration? Others may try further experiments. The best alcohol for these purposes, is that which has been gently distill'd in a tall vessel, with a quantity of dried fixed alkaline salt of tartar, by means whereof its watery part is so thoroughly absorbed, that it is impossible by any further art to procure the least drop more. With such were my experiments made; as being sensible of the close union between water and pure spirit of wine, which is not otherwise easy to be dissolved. The ingenious M. *Geoffroy*, the younger, has since given some curious and exact observation on this head, tho' with a different view (*n*). My chief curiosity was to learn what change it is that inflammable matter naturally undergoes, when being committed to the fire it turns to a pure flame; and at the same time what alteration happens to the fire, while this combustible matter turns with it into flame; being of opinion that if this were once discover'd, the way would be prepared for a thorough insight into the nature of fire. Accordingly, I provided a matter, which being burnt in the cylindrical vessel, and thus forced to pass wholly through the flame, which cover'd the entire surface of the fluid, served to nourish the flame, and was wholly converted into it, without either smoke, soot, or fæces. This I found catch'd fire in the air, without which there is no flame, and turn'd into flame itself, which afterwards afforded a liquid vapour, that at last resolved into water, or at least generated water; and having gone thus far, I could proceed no further: though, had I leisure equal to my inclinations, I should endeavour by these glass bells to procure a large quantity of this water, having found that much the greatest part issues out at the upper orifice; so that if a similar bell was suspended over this, the vapour, after its exit, might be caught again, and condensed into a sensible liquor: over this also a third might be placed, and by such means the whole vapour be caught. A very cold season would be fittest for this process, that as the vapour arises it might be presently condensed by the force of cold, and freeze as it were on the surface of the upper bells. The driest weather also, and a dry still place would be most favourable to the experiments. By such means I do not doubt but a discovery might be made of the greatest importance both in physics and chemistry. We find M. *Geoffroy* infers from his experiment, that pure alcohol by this burning will yield above $\frac{1}{2}$ its quantity of water; and that his experiment succeeded thus, is beyond question: but that excellent chemist cannot be

(*n*) See the Memoirs of the Royal Academy for the year 1718.

be ignorant how closely a large quantity of water will lie hid in air; how subtilly this will slide out of the air into saline and dry spirituous bodies, and mixing unperceived therewith, lead the observers into errors. 'Tis certain the dryest sulphur, when kindled, exhales into the air in a blue flame, and will yield, when collected, a very sharp acid liquor, which, if the operation be perform'd in a dry season, will indeed be in very small quantity, but so much the stronger: whereas in moist cloudy weather, the liquor, collected from sulphur, kindled under the bell, is more copious, but at the same time very watery. The same sulphur, in a clean vessel, by means of a gentle fire, will yield a great quantity of inspid water; and what remains will still afford a small quantity of a thicker and more acid fluid; which being exposed in a wide vessel to the open air, the water of the atmosphere presently unites itself with the acid, increasing its bulk and weight, but at the same time weakening its strength, and adulterating its purity; and it is not improbable, that the same happens to spirits in deflagration. These things put me in mind of the ancient alchemists, who call the motive of presiding spirit, the son of the sun, the issue of fire, and the internal fire of things. Probably all that is purely inflammable in bodies is only the spirit, or the smallest part of such matter, distributed through a large quantity of water intimately united with it, and disposed, on its contact with fire, to turn into flame; and in vain may we endeavour still further to pursue this subtle fugitive principle. I own myself tired in the pursuit, having desired nothing more sollicitously for a long time, than to understand the true nature of this inflammable principle in alcohol; as knowing this to be the true perfect inflammable body; and as knowing by experiments, that other bodies only become inflammable, as they contain some proportion of this alcohol, or at least of something exceeding like it in point of tenuity; since the other grosser parts remaining after the separation of this subtil one are no longer inflammable; so that I promised myself, if I could once discover this in alcohol, it would be easy to find the manner wherein fire is maintain'd by fuel in all other combustible bodies. But how great was my disappointment upon finding that alcohol, by passing through the fire, becomes a vapour, which no longer retains the nature of alcohol, nor seems to be any thing more than pure water. This shews us some fix'd limits of science. The pabulum of fire, when consum'd by it, leaves water; and itself becomes so light, as to dissipate into the chaos of air, and thus eludes all further pursuit.

And an insensible part.

EXPERIMENT IV.

52. My sentiment concerning the pabulum of fire is further confirm'd by the following experiment. Put a pure live coal without smoke in a perfectly dry earthen pan, and over this lay a brass dish well clean'd, being about an inch deep, its bottom orbicular, and about five inches in diameter; into this pour pure alcohol to the height of about half an inch, and place the glass bell over all; you will here have an opportunity of seeing how the fire

Instantaneous production of pure flame.

See Plate IV. Fig IV.

fire in the pan will make the alcohol boil pretty strongly, yet without catching fire, or emitting any visible fume into the cavity of the bell; and even though it evaporate from so large a surface, yet no visible fumes issue at the upper orifice of the bell; in the mean while, on the sides of the bell, especially towards the lower parts thereof, we shall find a kind of streaks or *striae* of the spirits running on the glass. If, after a considerable part of the alcohol is wasted in boiling, and exhaled out of the brass dish, we apply a lighted candle to the upper orifice, the flame will flutter over the same, and not give fire to the fumes within the bell, but rather be extinguished thereby: from whence it may seem to follow, that as the alcohol thus diffused through the bell does not take fire, the preceding experiment is no proof that alcohol, when burnt, may not have lost its inflammability, yet still remain alcohol, since the same is here lost by mere ebullition and exhalation, without being kindled. But by attending further to the sequel of the experiment this difficulty will be removed. Taking then the lighted candle for safety's sake in tongs, and applying it cautiously, in a horizontal line, along the table, under the lower edge of the glass bell, it no sooner comes in contact with the fumes dispersed over all the cavity, than the whole immediately catches fire, and discharges like a clap of thunder; whilst the flame rushes forcibly out from under the edges of the bell. The reason is, that the cavity of the bell being before full of minutely divided alcohol, and this all kindling at once, the vessel cannot contain so great a flame, but must discharge the greatest part of it into the open air beneath the bell; which must be left a little open at bottom, or there will be danger of its being all blown up or burst in pieces, unless there be space enough at the bottom for the flame to vent itself. The foregoing cautions must be well regarded in repeating the experiment, otherwise the face, hair, and hands of the operator would run great danger of being scorched.

53. At the moment the flame is thus produced under the bell, the whole surface of the boiling alcohol in the brass dish catches fire, which did not kindle before, though, by the brisk fire under it, it boil'd strongly; by which it appears, that alcohol will not easily kindle without the application of a live flame; but the flame once catch'd by the alcohol, continues burning under the bell, till it be all consumed, and the dish left quite dry, when the flame ceases.

Whence boiling alcohol is fired;

54. What is most curious in this experiment is, that the flame excited by the candle, placed at some distance from the dish wherein the alcohol was boiling, should diffuse itself so copiously through the cavity of the bell, as to kindle the alcohol in the dish; and that in the moment when the alcohol was thus kindled, all the flame in the bell ceased, while that on the surface of the burning alcohol continued to the end, till the whole substance of the alcohol was consumed; nor did any the like flame appear again under the bell during the whole course thereof. Hence it appears, that pure alcohol, though urged by a vehement fire, provided it be not set on flame, will diffuse itself through vast spaces, and remain unchang'd therein without loss of its inflammability; so that by the application of a live flame thereto, it will instantly catch fire, and burn vehemently. Yet this same alcohol,

And whence the flame is extinguished.

T t

upon

upon being forced to pass out of its vessel through the flame incumbent on its surface, and thus becoming a nutriment to the fire, and thence diffusing itself through the cavity of the bell, has lost all its disposition to catch fire; so that tho' now its matter be much more attenuated by the fire than before, it will no longer catch flame from the fire on the surface of the alcohol.

55. This phenomenon deserves mature consideration; for it does not seem probable, that fire could in a moment's time have expell'd all the alcohol it had burnt, out of the whole cavity of a large bell; but if, as is most likely, the matter of the alcohol arising from the flame, and floating in the bell, had continued inflammable as before, it must necessarily have catch'd fire from the same flame. What shall we say then, when the only pure inflammable matter known to us in all nature, after having once been kindled, loses all its inflammability; does it not follow hence, that so much of the pabulum, or alimentary matter, of fire is destroyed and lost in the universe, as is the quantity of flame exhausted daily? and must not this at length fail, unless it can some way be regenerated? Is not the pabulum of fire in the earth continually recruited by the course of nature's operations, particularly those which generate oil and spirits; as vegetation, fermentation, putrefaction, and distillation? And yet all these operations, in nature as well as art, are performed by the mere power of fire; so that the same fire which destroys combustible matters does also reproduce it in the universe. Or shall we rather adhere to that other doctrine above proposed, *viz.* that matter perfectly combustible by fire consists of a great proportion of water, and a small quantity of some other subtle principle, which is like fire, and perhaps no other than fire itself united therewith; and that in burning, this fire being separated from the water, is left entirely at liberty, and perhaps may thus constitute the element of fire? In this case fire itself will be the last inflammable part, and consequently, when separated from all other adhering bodies, must vanish into air.

EXPERIMENT V.

Flame extinguish'd by oil.

56. A lighted candle being immersed in cold and pure oil of turpentine, is extinguish'd thereby, as if it had been plunged in water, as was above specify'd in alcohol. Likewise if a live coal be thrown into the same oil of turpentine, it is immediately extinguished without raising any appearance of a flame: whence again, most of what has been said concerning alcohol may also be understood of this oil.

EXPERIMENT VI.

Flame increased by oil.

57. Putting some pure distill'd oil of turpentine in a brass cylinder, and setting it on the fire till it boil, if while under ebullition, we hold a lighted candle to its vapour, it will at length catch fire, though not so readily as alcohol; by degrees also it emits a black smoke, upon the appearance

appearance whereof, it burns violently : it leaves scarce any fæces at bottom, but consumes almost wholly, and by how much the purer and more limpid this oil is, the less of the black smoke it yields, and the more quietly it flames ; and by repeating its distillation it grows still purer, leaving some fæces every time, and thus approaches still nearer to alcohol, both in respect of levity, limpidity, purity, and flame : but however near it approach to alcohol, it never becomes alcohol, as being incapable still of mixing with water.

EXPERIMENT VII.

58. Expose the same oil of turpentine in a brass vessel to the fire till it boil, then kindling it, lay it on an earthen foot under the glass bell, it will continue to burn as in the preceding sixth experiment ; but it will yield a thick black smoke through the upper orifice of the bell, and even fill the whole space of the bell and the sides of it with a fuliginous vapour, and a watery moisture, which, hanging to the vessel, distils a watery liquor, so that one would conclude, that water were here produced from burnt oil ; or at least from something which the air contributes thereto. Hence it appears, that oils nearest a-kin to alcohol, when urged by flame, and forced to pass through the same, emit some parts still inflammable, and not thoroughly burnt, but retaining the characters of a coal ; which arising out of the flame in form of a fuliginous smoke, and proceeding till they have spent their first motion, adhere to the sides of the chimney, or the like. The same also appears from the fetid smell diffused by burning oils ; but they seem too thick and tenacious to be so suddenly destroyed, or reduced to the extreme tenuity of alcohol, by the action of a swift transient flame : and when the same oils, in common lamps, burn slowly away with a wick, surrounded on all sides with air, they yield a much greater quantity of soot ; as appears by holding a clean paper over the flame, which will presently be covered over with blackness : but when lighted in our present cylindrical vessel, the whole surface of the oil being here covered with flame, and consequently all the particles of the oil to be burnt undergoing the agitation of that flame, they become much more attenuated and altered than is usually found in lamps, where from every point of the surface of the flame there is a free passage for the oily particles to escape into the air, even while many of them have undergone but half their change : from all which it appears probable, that could we by any art render oils as thin and subtile as alcohol, they would produce a flame without smoke, and fire without soot.

The flame of burning oil examin'd.

EXPERIMENT VIII.

*Water and
alcohol exa-
mined, while
burning toge-
ther.*

59. Mixing equal quantities of fair water and pure alcohol in a clean brass cylindrical vessel, so that after shaking them together they form'd one homogeneous liquid; then heating this mixture, and setting fire to it under the glass bell as before, we find a much weaker fire produced than in the first experiment; nor is the bright glittering colour of this flame comparable to that of mere alcohol. This flame growing very weak long before extinction, at last leaves behind it in the bottom of the vessel, a quantity of water, with a very small remainder of the alcohol in it; as appears by the taste. Hence we learn that alcohol, when mix'd with water, may be again separated therefrom by means of fire, and be consum'd by the fire, while the water is repell'd both by the fire and the alcohol.

EXPERIMENT IX.

*The flames of
alcohol and
camphire.*

60. Taking a quantity of pure alcohol, wherein the best camphire was dissolved, and kindling it under the circumstances above described, and placing it when on fire under the glass bell; at first they burn as if there were nothing but pure alcohol, all the phænomena whereof they exhibit. In reality, it is the pure alcohol alone that is first consumed; the camphire, which gathers to the bottom of the vessel, not coming yet in play: but when once the alcohol is consumed, we find a new flame, very different from the former, arise, being both stronger, brighter, whiter, and more darting; at the same time a black smoke also proceeds from the flame, and the smell and taste of camphire spreads plentifully, not only over the vessel, but through the whole place. And thus the flame continues to the end, leaving no fæces behind it; from which we learn, that if inflammable matters of different natures be mixed into one compound, they do not burn at the same time together, but the more subtile part consumes first, and the remaining grosser part, after having defended itself so long, the former being quite dissipated, begins to burn in its turn. By this it should seem, that among combustible bodies, the lightest always burns the soonest and easiest; as also that the flame of kindled alcohol alone is too weak to set oil on fire: whence it is, that as soon as the oil, or in this instance the camphire, begins to burn, the fire becomes much fiercer than before. Again, hence we infer, that fire in the burning, as well as distilling of bodies, divides visible inflammable matters, combin'd in the same combustible, according to their different degrees of subtilty or thickness; so that first spirit, then a thinner oil, then a somewhat thicker oil, and lastly a very gross, pitchy, tenacious oil rises in flame. Hence also it is that charcoal, which consists of this last grossest oil spread over earth and salt, affords a much stronger fire, than the wood of which it is prepared could of itself ever have produced; since we find in all bodies, that the fire of any kindled oil is constantly

constantly the stronger, in proportion as such burnt oil is heavier and thicker: which also obtains in the burnt alcohol and camphire; and of which we shall have further confirmation in the sequel of these experiments; where it will appear, that the fire is always the hottest, when it comes to consume the last inflammable part of the fuel. Upon the whole, therefore, we are not to look on the kindling of combustible matters by fire, as an action which mixes all inflammable materials, and burns them together, but separately and successively.

EXPERIMENT X.

61. We proceed now to a like examination of alcohol intimately mixed with a distilled oil, *viz.* thin oil of turpentine; so that the two appear to form one homogeneous fluid. Kindling some of this mixture in the same cylindrical vessel under the bell, as before, the first thing that appears is a strong, equable, lucid, cloven flame, which, so far as we can find, produces no appearance of smoke, nor generates or deposits any soot, and yet blackens a clean paper held over the orifice of the bell; which shews, that even in so pure and simple a liquor, something immediately arises from the mixture, which makes its way through the flame, before it has been quite burnt thereby: yet no stench is perceived from such vapour of the flame, which burns very quietly, without yielding any crackling or noise. But after the flame has consumed the alcohol, a new face of things appears; for the oil of turpentine remaining at the bottom, begins now to burn, fly, crackle, hiss, and smoke plentifully, yields a black soot, and at last goes out, leaving behind it a resinous matter, which will burn no longer with this fire.

EXPERIMENT XI.

62. By mixing equal parts of pure alcohol and the alkaline spirit of sal ammoniac, we produce that surprising *coagulum* mention'd long ago by Lully, and further celebrated by Van Helmont. Upon setting fire to this, as we did to the former, the alcohol first kindles; which being consumed, the flame goes out, leaving at the bottom of the vessel almost the whole quantity of the spirit of sal ammoniac. In this experiment, therefore, the *off a Helmontii*, as it is called, is first heated, then set on fire, and put under the bell, where in the first place it yields a weak, equable, scarce visible flame, without smoke or soot; but with this circumstance, that the lower part of the bell becomes very opaque with the vapour. Secondly, the flame grows stronger, brighter, sparkling, hissing, unequal, and vibratory a little before its extinction, and now yields a smell of a volatile alkaline spirituous salt: the vapour, collected into a liquor on the sides of the bell, is almost insipid, and at the bottom remains a strong sharp urinous spirit, very volatile and odorous; and what is very remarkable, the salt in the spirit of sal ammoniac is much more volatile than alcohol itself, as appears by slowly subliming.

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ming the *off a Helmontii*, when the dry salt always rises first: yet in burning the mixture, the alcohol always consumes the first, being first drawn up to the flame; and though the mixture be heated in a brass vessel, and vehemently agitated by a fire over it, yet that exceedingly volatile salt will tend with its water downwards, till it be stopped by the flame, thro' which it cannot pass to disengage itself. Hence we may observe how little the true nature of flame and combustible matter has hitherto been understood; and as camphire is held by many eminent chemists to be a solid volatile oily salt, form'd like the *off a Helmontii*, of the same two saline and oily principles, it may be worth while to burn this also under the bell. This we find easily kindles upon the application of a burning candle; and the flame it produces is very extraordinary, being white, equable, long, slender, and terminating in a smoaky cone; filling the bell with a copious, dense, black smoke, and at the same time black, fuliginous particles are thrown out from all parts of the flame, and so ponderous, that they fall to the bottom, where they still retain the smell and taste of camphire, notwithstanding their blackness: scarce any fæces remain at the bottom after the burning is finished. From the whole we may form some judgment of that wonderful body, *viz.* that it is a most perfect simple resin, or oil in a solid form.

E X P E R I M E N T XII.

Alcohol and earth.

63. Taking pure *English* chalk, reduced to fine powder, and mixing therewith an equal quantity of alcohol as intimately as may be, put the whole under the bell as before; the alcohol will burn away first, as in the third experiment, and the earth, after the deflagration, remain entire, pure, dry, and unchanged at the bottom.

E X P E R I M E N T XIII.

A mixture of alcohol, oil, camphire, off a Helmontii, and earth.

64. The most entertaining experiment consists in mixing together alcohol, camphire, and oil of turpentine, as accurately as may be, and adding to these the *off a Helmontii*, which easily mixes with any of the former, bringing these into a mass with fine *English* chalk, and lastly adding saw-dust to the whole; set fire to the mixture, with the circumstance above expressed; the effect will be, that the alcohol deflagrates first, almost after the same manner as if this alone had been kindled. This being consumed, the oil of turpentine kindles, and exhibits its particular phenomena already specified; next the camphire burns, as appears by the several characters thereof: the alkaline spirit of sal ammoniac, the saw-dust, and mere earth remaining at the bottom. It may be observed, that the flame is very strong, unequal, red, and crackling; that it yields little smoke at the beginning, but that the smoke gradually increases, and becomes extremely black and thick; the foot also towards the end is very black and thick, and at the close of the whole we see fuliginous *floci* floating confusedly through the bell; and the flame during the whole never touches the wood.

65. From the whole we have an opportunity of learning the manner which nature makes use of, in consuming combustible fewels by means of fire, which 'tis certain is very different from what is vulgarly imagin'd. At the same time it appears, that nothing in all physics is more difficult to be ascertain'd, than wherein the properly combustible part of a fewel consists: 'tis easy to enumerate the names of alcohol, oil, and sulphur, to which is generally falsely added nitre, and to say that these are the inflammable part; but to extricate the true inflammable principle out of all these, is a matter of immense labour: nor do I find any writer has hitherto done any thing considerable in it; far from having shewn what change it is that fire makes therein by burning.

SCHOLIUM I.

66. (1) In the first place, therefore, there appears to be a liquor in nature, *Alcohol the only pure inflammable substance.* produced from vegetables by fermentation and distillation, which of all others is the simplest, lightest, most limpid, moveable, unchangeable, and perfectly miscible with water and oils; and which, when heated with fire, may be kindled by the application of fire, so as to burn away and maintain a pure flame throughout its whole surface, contiguous to the air; and thus by degrees turn its whole substance into flame, so that as long as a single drop of it remains the flame will subsist, but when this is totally exhausted, the flame at the same time intirely disappears: we have, therefore, found a body, which truly deserves the name of a food or pabulum of fire, since it appears to our senses that it may be absolutely and wholly converted by burning into pure live fire or flame. And now, if we consider what becomes of the alcohol in the experiment, we shall find it turn'd to nothing but pure flame; which flame, thus produced and fed by it, has all the effects of true fire, and exhibits all the physical characters above laid down in the history of fire (p).

66.

(p) "The flame of a body, Sir I. Newton observes, is only the smoke thereof heated red-hot; and the smoke is only the volatile part of the body separated by the fire. Thus, all inflammable bodies, as sulphur, oil, wax, wood, &c. by flaming, waste and vanish into burning smoke; which smoke, if the flame be hastily put out, is very thick and visible, and sometimes smells strongly, but in the flame loses its smell by burning; and, according to the nature of the smoke, the flame is of this or that colour. Thus, the flame of sulphur is blue: that of camphire, white; that of tallow, yellow, &c. When gun-powder takes fire, it goes off in a flaming smoke; the explosion arises from the violent action of its ingredients, nitre, sulphur, and charcoal upon each other; whereby the mixture being suddenly and violently heated, becomes ra-

ised and converted into flame; which, by the violence of that action becoming hot enough to shine, appears in the form of flame. Flame I take for a mixture of fire with the oily part of the fewel; and this oil, being the sulphureous part of the mixt, i. e. the part wherein the fire that acts therein is lodg'd, is more disposed than any other part to admit and retain a quantity thereof. A quantity of fire then being enter'd into such oil, must extend its mass, and augment its bulk so far as the oil is capable of stretching, at the same time filling all the interstices thereof with its own substance. Thus the mixture becomes what we call flame; which, therefore, is an oily body without pores, or whose pores are exactly filled up with the globules of fire contained therein."

*Sustains flame
of itself.*

66. (2) Another thing we learn hereby is, that the fire thus collected about alcohol remains still free, as long as the alcohol remains without any other fire added or conveyed to it by any other art; so that when once kindled, it would remain the same for ever, nor needs any other fuel to keep it up in the open air.

*Yields no
smoke, but
water.*

67. (3) Thirdly, we also learn, that when the alcohol is consumed, there remains nothing of the fire and flame, which disappear at the same moment with the alcohol; and consequently, that this fuel is the true cause which produces at least the presence of all that fire: the fire remains no longer than the pabulum, nor ceases while any of that remains.

68. Fourthly, what is very remarkable in this pabulum, and the flame produced by it, is, that from the moment of its beginning to burn, to the moment it goes out, it emits not the least smoke; which is commonly found in all other bodies, at least either at the beginning or end of the flame. 'Tis true, this flame of alcohol emits a humid vapour; but then this is as limpid and transparent as water, and when collected, produces a mere pure water, without either colour, grossness, or oiliness. In effect, we may lay it down as a rule, that there is no other body, whether fluid or solid, hitherto discovered, which nourishes fire without affording any smoke, except alcohol alone.

No ashes.

69. (5) We learn from these experiments, that there is not any fix'd incombustible matter in alcohol; since, when perfectly pure, as is always necessary in this experiment, it leaves not the least stain behind when burnt, but turns totally into mere flame, without leaving any fæces. Nor is this again found in any body excepting alcohol; all others constantly leaving some fæces behind, incapable of being burnt further; though some of them very little. Naptha, petroleum, and camphire burn vehemently, and turn into bright flames, but are always found to leave something less combustible behind them at the bottom of the vessel they were burnt in; alcohol alone leaves nothing.

*No smell but
of alcohol.*

70. (6) Again, we learn that alcohol, thus burnt, yields no smell different from what it naturally affords without burning; the like of which is not found in any other combustible matter, which always yields something rank, fuliginous, or empyreumatic, at the time when they are converted into flame: whence one would be apt to imagine, that all the parts of alcohol remain homogeneous, and the same both before, in, and after the burning, were it not for what we have observed of the water arising from the flame of alcohol, wherein there is something not combustible.

*Solidity not
requisite in
fuel.*

71. Seventhly, we also learn hence, that the one only body, which has all the above-mentioned properties in the fire, does not appear either by the sharpest sight, or the best microscope, to have any solidity or firmness in it, and consequently that a solid form is by no means necessary to the constitution of a pabulum of fire; but rather the most fluid of all bodies hitherto observed.

*Alcohol holds
water.*

72. (8) We have also learnt, that this alcohol is of such a nature, as to attract, imbibe, and retain the purest elementary water; and that the flame produced in alcohol again attracts from the water and alcohol mix'd together,

together, the sole pure parts of alcohol, brings them up to the surface of the mixture, and here absorbs and turns them to flame; thus separating them from the water, which it rejects, and leaves to settle at the bottom of the vessel.

73. (9) Again, we find that an alcohol, having all the same properties, may be procured from all known vegetables, by previous fermentation, and subsequent slow distillation: but excluding vegetables and fermentation, there will be no other body or means in nature, whereby to attain a fluid of similar properties. *Produced from vegetables.*

74. (10) Again we learn, that in this alcohol, however pure, there is still a diversity of parts, which is not discoverable by any other art, but by burning alone; and which, by means hereof, produces a water capable of extinguishing fire, and another inflammable part, which totally consumes and dissipates in the fire. *Its composition.* Helmont affirms, that by the addition of salt of tartar, he could immediately convert the purest spirit of wine into half the quantity of pure water, leaving the other part behind in the alkali; but I have always doubted whether this were not to be understood of unrectified spirit of wine, in which it holds good, rather than of true alcohol produced by the strictest rules of art; in which, I believe, it never has hitherto been demonstrated. From the whole it appears, that alcohol is much like sulphur, since both consume in the fire, both yield a blue flame, both turn into one part inflammable by fire, and another which extinguishes fire, and which in alcohol is a mere water, and in sulphur an acid salt of vitriol, diluted with a little water, whence its vapour becomes suffocating.

75. (11) Lastly, we here find that solid vegetables burn by the same law as fluid, and are changed and agitated in burning after the same manner; *Other few will burn as alcohol.* viz. the inflammable part alone being consumed by the fire, and the others dissipated into a matter, which, when collected, becomes visible again, and sometimes also combustible again, and lastly into a fix'd part, called ashes or fæces.

SCHOLIUM II.

76. (1) It appears that alcohol bears a similitude to fire, of which we have many indications; both of them coagulate blood, serum, and bile, and, as it were, parch up the flesh, blood, nerves, viscera, the white of eggs, and bread. *The agreement betwixt alcohol and fire.* Does it not even appear as a magnet of fire, since it attracts the light when held to it? And does not alcohol when committed to the fire, heat along with it till it boil, and thus emit flame?

77. (2) All other inflammable fluids, however subtle they be, yet when kindled after the manner above specified, always afford a visible black smoke and foot, as also some fæces or remains, not quite combustible. *All other few will leave fæces.* This inflammable part in the purest oils, is first mere earth, wherein there always remains a little portion of the oil, on account of which it retains the nature of a coal, and has always something inflammable remaining; and if such oils be further purified by repeated distillations, they always deposite a proportion of earth, become still thinner, finer, and more combustible, yielding

ing still less smoke, soot, and ashes, and approaching nearer and nearer to the nature of alcohol: but though the operation be continued ever so long, it does not appear that they are reducible to such a degree of subtilty, as to dissolve and mix with water.

*What would
fired alcohol
be without
water?*

78. (3) The only known body, therefore, that is absolutely and wholly inflammable, so as to nourish flame, yields no smoke, nor produces the least soot, or leaves any fæces when burnt, but passes in its whole substance, so far as our senses may judge, into fire; excepting that it affords a little pure water. If then it were possible by any art to separate the combustible part of the alcohol from the water, and thus commit the first part alone to the fire or flame, what must the result be? Would it then burn successively, as it does now when intermix'd with water; or would it not rather go off and consume instantaneously like lightning? The imagination would suggest many things on this head; but we must check its forwardness by the weight of experiments.

*Pure pabulum
of fire totally
vanishes in it.*

79. (4) From what has been said, we may venture to affirm, that the part which is not absolutely inflammable in any combustible vegetable, as alcohol, or any oil, either consists of water adhering intimately to them, or of salt, or lastly of earth; and that if these could by any art be perfectly separated from the oil or alcohol, the remainder would be simple, pure, perfectly combustible, and yield the purest flame without smoke, soot, or fæces. This holds so true of the limpid subtile vapour, collected in the bell during the burning of alcohol, that itself is only the watery incombustible part of the alcohol; consequently all the ashes, smoke, and soot mix'd in a true inflammable body, consist of water, salt, and earth.

*Smoke and
ashes, what.*

80. (5) We also learn that smoke, soot, and the visible fumes of a burnt vegetable, are always the more copious, by how much there was more water, salt, and earth contain'd in them, in proportion to their oil and alcohol; as may be fully made out from the above experiments. In reality, those bodies in burning afford such parts, which being violently agitated by the flame, are incapable of being converted into the subtile fleeting matter, but are again either expell'd from the flame upwards, or fall downwards. If we compare green wood, when laid on the fire, with the same wood after it has been dried a considerable time, so as it have preserved its oil, the truth of this doctrine will be still further confirm'd.

*Whence bodies
prove less
combustible.*

81. (6) Again, we learn that in a vegetable combustible body, the incombustible parts, viz. water, salt, and earth, may chance to predominate so far, as that the other combustible part alcohol, or pure oil, cannot be kindled, but only emit a mere smoke. Thus alcohol, when mix'd with a hundred times the quantity of water, though it be heated beyond the degree of boiling alcohol, will not kindle; but if cast on the fire, puts it out: and wood, though very oily, yet if it be green and full of water, will yield plenty of smoke, but no flame. So fat potter's clay doubtless contains oil, which, when separated, will burn, but is so check'd by the prevailing earth mix'd with it, that the small quantity of oil cannot burn therein.

*Fire the
greater in
less combusti-
ble fuel.*

82. (7) One thing remarkable, proved from the preceding experiments, is, that if the fire applied in a combustible vegetable, consisting of a combustible

bustible and an incombustible part, exert so much power, as at the same time, and with the same action, both to kindle the combustible part, and divide and attenuate the incombustible one into minute particles, and the flame thus produced by the joint action of the combustible and incombustible matters, will be much stronger than what the combustible part alone, if collected and kindled by itself, would have produced. For flame, *ceteris paribus*, is always found the weaker, by how much the matter of which it consists is purer; consequently also the flame produced by such a mixture will be much more unequal, than that which would have been produced by the pure inflammable part alone; and hence the fire arising from such a mixture is more audible, crackles, flies, and is often very troublesome, as well as more smoky and soeculent, than that of a purer matter. In fine, the more incombustible matter there is in fuel, the more violent will the fire be, provided it can be kindled at all.

83. (8) This also will hold every where true, that by how much the incombustible matter united with the oil is denser, more compact and ponderous; by so much will the fire and flame produced by such combustible body be more violent. *And the more ponderous.*

84. Thus, we not only find that, in the same vegetable, its more solid parts produce a stronger fire than the other looser parts, *sc. gr.* the wood, than the blossoms or leaves of trees; but also, that different woods, if compared with each other, always yield stronger or weaker flames, as they are more solid, or more loose and fungous. Cedar, for instance, yields a much stronger fire than willow; sideroxylon than poplar; and this in proportion to the heaviness of the one beyond the other.

85. (9) We also gather from the preceding doctrine, that no vegetable burns till it be first heated by fire, and this to a degree sufficient to make oil boil; but lighter bodies heat sooner to that degree, by the same fire, than heavier ones: whence it may be infer'd, that heavier fluids kindle slower, and lighter sooner. Accordingly, we never see matches made of solid oak, but always of spongy deal or sedge. But the sooner a body kindles, the weaker is its flame; and the slower, the stronger and more durable; on the whole, so much the more fire must always be supposed pre-existing, by how much the wood to be kindled is the heavier; otherwise it will not be sufficiently heated to catch fire. *No fuel burns of itself, but by fire.*

86. (10) Again, it follows from what has been said, that in the burning of vegetables, the combustible part is always consumed by a successive, and not an instantaneous or momentary action of the fire: add, that in such a burning, the consumption and separation of the combustible matter is always successive; so as that the purest and lightest among the materials to be burnt, always kindles and is separated and changed the first; as this grows hot the soonest, and is easiest moved and disengaged from the rest. When this is consumed, the matter next to it in degree of inflammability, &c. begins to be agitated, heated, kindled, and separated; which being at length consumed in its turn, the others will succeed; and last of all that which is least inflammable: and this last appears by a multitude of experiments to be a little quantity of oil strongly adhering to a large portion of

And this successively in a certain order.

fix'd earth. Whence again it appears, why in a close vessel, without admitting fresh air, this oil cannot be separated from its adhering earth: and hence also we may learn, that this last incombustible part will never yield a violent fire, on account of the excess of the incombustible earth in proportion to the combustible oil; whence, though it be capable of being ignited and shining, it will rarely break into flame.

*Fire, why
strongest at a
certain time.*

87. (11) We may also observe, that a fire kindled by a compound combustible body burns, with the most vehemence when it is about the middle of its burning, *viz.* when all the parts are the most rapidly kindled; since towards the end, there is usually need of bellows to keep it brisker; otherwise the terrestrial and saline fix'd parts, by the ashes which they spread over the fire, are apt to deaden and extinguish that little, which is kept alive in the small quantity of oil.

*Why weak in
alcohol.*

88. (12) Hence we also learn, that the purest of all flames produced by a mere combustible matter, without any admixture of other substances, can never yield a very strong fire, though it will a very equable one; since in the preceding experiments it has been shewn, that the purest pabulum yields the weakest fire.

*The effect of
incombustible
parts in fire.*

89. (13) Contrary to the common opinion, we gather, that the power of flame depends as much, or perhaps more, on those incombustible parts contain'd in the kindled matter, as on those which are truly combustible; and therefore, that the quantity of fire in flame, produced by a combustible matter, is rather collected into the space of the flame, by the rotation of the unchangeable particles mixed with the rest, than by that other thin volatile oily part, more immediately agitated by the fire.

*A double mat-
ter in flame.*

90. (14) We may hence infer, that there is a double cause in material fire; *viz.* first elementary fire and its proper genuine pabulum, which is mere pure alcohol; and, secondly, in this pure and proper fire, there are also other parts, which alone could not have sustained elementary fire; but when agitated in the former pure flame, increase the violence thereof by their own vibration, which frequently, by this means, is raised to a pitch much beyond what could ever have been produced by the former cause alone. To illustrate this point; suppose half an ounce of gun-powder kindled in the open air, and spread all around into a flame, and thus in a moment disappearing; suppose then the same powder ramm'd into a cylindrical barrel, and after this a suitable ball of lead, and then the gun-powder kindled; the powder will now, by its proper motion, project the leaden bullet out of the barrel with an incredible force; of which we had but small signs in the particles of the gun-powder, when kindled before in the open air: whence it appears, that the like hard incombustible bodies, being whirl'd about and vibrated in so rapid a flame, may add great power to the body of the flame.

*Fire, how
heighten'd.*

91. (15) The utmost power, therefore, of this fire may be heighten'd by water, salt, and earth, intimately mix'd with the combustible matter, and with one another, in the pure kindled fire; provided that fire be strong enough to put them in a quick motion.

92. (16) Some cause is necessary, in order to preserve and continue the flame when once kindled; and one condition of such cause must be, to make the pabulum during the burning remain closely join'd to the fire itself, and prevent the separation between the two; which otherwise the fire naturally tends immediately to make. Another effect hereof should be, to keep the hard incombustible parts, when agitated by the force of the former, within the space of the kindled fire, that they may not hastily fly off, but be retained in the place where they are so agitated, in order continually to receive the impulse thereof: for without such a cause, all this matter, thus agitated, must be every moment flying off from the fire, which would put an end to the action of these vibrating particles within the sphere of the fire. Whence again it appears, that all fire would only be momentary, were it not for this cause which applies, presses, and unites it to the matter. Yet it does not appear, that this compressing cause should so act on them, as by the pressure to reduce them into a motionless mass; the effect of which would be, to suffocate the fire; but such a compression seems chiefly necessary, whereby the grosser parts, whether combustible or incombustible, after having been agitated by the fire, may successively fly off in proportion as new parts begin to be agitated; and the cause which seems fittest for this purpose, is such as may effect this by a reciprocal oscillatory compression, or remission, being itself all the while intirely fluid, and incapable of being consolidated.—Such a cause is the atmosphere, which surrounds and presses upon all bodies at all times; this therefore seems the place for ascertaining what the power of the atmosphere contributes to the maintenance of fire.

93. Suppose then a fire made of the best wood, thoroughly kindled, on an iron plate, so that its base be a *Rhinland* foot square; the weight of the atmosphere incumbent on the base of this fire will be that of a prism of air, whose base is a *Rhinland* foot square; the weight of such a prism is found by the barometer to be different at different times; but with this restriction, that the difference between the heaviest and lightest states rarely exceeds $\frac{1}{10}$. Suppose then, at the time of our experiment, the height of the mercury in the barometer to be 30 *Rhinland* inches; and suppose the weight of mercury to that of water as 14 to 1, and that a foot of water at such time weighs 64 *Troy* pounds, the pressure of the atmosphere incumbent on the square base above-mention'd must be 2240 such pounds; and this immense weight is then acting on the fire: but the live parts of the same fire are every where endeavouring to remove and cast off this load with vehement force, and by such means expel all the heavy parts of the atmosphere out of the place where the fire is kindled; which again increases the weight of the atmosphere itself. Now, by the laws of hydrostatics, the resisting fluid of air thus repelled, must press on all the points of the surface of the fire here kindled, which of consequence must be impelled and acted on from every side by this weight with an equal force, as if compressed by a vault so strong as to bear a load of 2240 pounds without bursting; so that the inflammable parts in this fire being agitated by the force of the elementary fire collected therein, and at the same time all the other incombustible particles being acted on by the force of both the former

The cause uniting fire to its fuel.

The physical manner of fire's acting.

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mer, when they endeavour to fly off from the fire, they will be repelled back towards the centre of the same fire by so vast a weight; and this continually, but still more and more, as the fire within acts more strongly. Hence again we learn, that both the particles of the fire, and the combustible matter, will be applied and compressed with immense force against each other; and at the same time be rapidly agitated, and shaken around by the incredible force of the fire, which dilates all; by such means a vehement attrition must be excited between all the solid parts, which will be proportionably greater, as the force wherewith they were pressed together, and the attrition of the fire is greater. And the fire, burning with the combustible matter, acts always with equal concussions on the atmosphere, which still makes an equal resistance; consequently the fire by this perpetual recidivation of the atmosphere, will be impell'd much after the same manner, as if continually beaten with a hammer of 2240 pound weight. And again, as the air over the fire must be in a continual ebullition, like that we find over a live coal, when exposed to the sun, and viewed with the eye directed above the coal towards the sun: it will follow then, that the strokes or pulsations of so elastic a fluid in such a vehement ebullition, will be so much the stronger, and succeed the thicker; and that if less resistance be made from one part of the fire than another, the air will rush more swiftly against that part in proportion; till being rarified and repulsed by the fire, it makes a continual and vehement oscillation over the whole compass of the fire. So long, therefore, as there remains sufficient fire in this place to produce a flame with its proper pabulum; so long as the other parts can be strongly agitated by this flame; and so long as they are compressed by the aerial vault with sufficient force to prevent the flying off; so long there will be a sufficient attrition produced on this hearth, to collect a quantity of fire sufficient for the continuation of such a flame: but when either elementary fire is wanting to agitate, or fuel to be kindled, or that the particles to be agitated are too gross and hard to undergo the due alteration by those other, the fire will immediately begin to dwindle, and at length entirely cease. So if the aerial vault happen to be weaken'd, or render'd less ponderous, the fire on the hearth must be weaken'd proportionably; and when the former is much diminished, the fire and the pabulum will fly from each other, and dissipate in air. Hence all flame, and presently after, all fire and sparks go out in the vacuum of an air-pump, for want of a due application between the parts: hence wind increases the power of flame; the effect of this being the same as if the weight of the atmosphere on it were encreased: but if the wind blow so strongly on the fire, as to break the aerial vault about it, the flame will be immediately extinguished, and perhaps instantly re-kindled by the same blast which put it out: consequently if the fire be blown by bellows, supposing this be not done so forcibly as to extinguish it, the additional pressure of air must always apply the parts more strongly together, and thus breed a fiercer flame; and if two strong bellows be blown from opposite quarters upon the same fire, a violent flame will necessarily be produced in the middle of the fire, whereby metals will presently be melted, and other operations may be performed, as we find practised accordingly among goldsmiths and other workers in metals.

94. Hence, again, we see why fire burns so much the fiercer, as the whether is colder, and the air more constringed by a keen frost; the aerial vault surrounding the fire, then binding it so much the closer and stronger, and thus preventing the particles floating in the torrent of fire from flying off, till by the continued action of the fire they become so attenuated, as to be able to make their escape through the air itself. Hence also it happens, that the pressure on the fire is greatest about the upper parts, and least towards the circumference of the base; whence the air, finding least resistance from that part, drives the flame upwards: and as the fire is densest, and consequently strongest about the middle, it thence follows, that the flame will rise higher from the middle of the fire than from its sides, where the quantity of fire is considerably lessen'd; and hence we see the reason of the pyramidal figure of flame. But if the surface of the fire be every where invested with a hard body, which excludes the air; the pabulum, as also the rotation of the particles, and their equal pressure and resistance from all sides, presently rest among each other, and thus the flame ceases, and the fire soon goes out; though, upon removing this cover, and re-admitting the free air, it presently kindles again into a live flame, or at least in to a glowing fire.

Why fire burns strongest in cold weather.

95. (17) Lastly, from the consideration of all that precedes, it does not appear that there is any thing in nature, which, when committed to elementary fire, is changed into the substance thereof. In all the instances and experiments which have occur'd to me, I have examined very narrowly for an indication of this kind, but find none; and therefore dare not affirm, that either alcohol, oil, or any other body, becomes fire in burning. Indeed bodies perfectly combustible are so alter'd in the flame, that we can find nothing remaining of them, by any way of enquiry hitherto known; being so far subtilized, as to escape all notice of our senses: but it does not therefore follow that they are turn'd into fire itself.

Fewel does not become fire.

Of Fewels from animal Bodies.

1. **H**AVING examined the matter which is properly combustible in vegetables, we should proceed to a like enquiry of the fewels in animals; but it being evident that the bodies of animals consist of a vegetable matter digested in them, such an enquiry is in great measure unnecessary. If we may trust to history, the humours of the bodies of animals have been sometimes carried to such a degree of oiliness and subtilty, as to catch, like alcohol, a weak pure flame. To this effect we have instances of men, whose fumes as they perspired would kindle around them; and *Helmont* even speaks of a man, whose wind, broken downwards, if directed upon a candle, would turn to flame: but such instances, if true, must be allow'd very rare.

Animal exhalations sometimes inflammable.

2. The oils, however, of animals, scarce differ at all, in respect of inflammability, from those of vegetables; so that it would be to little purpose to repeat what has been already rehearsed. We find waters, spirits, salts,

salts, oils, and earths in animal substances; but the nature, preparation, purification, and effects of these in the fire, are perfectly the same as in vegetable substances; so that it may suffice to recommend it to the reader, and to compare and apply what has been said in the one to the other. Some indeed may suspect, on account of the phosphori obtain'd from animals, that the inflammable principles of these are somewhat different from those of vegetables; but to obviate this, we need only observe, that chemistry can also produce phosphorus from fat coals of vegetables, especially of those vegetables, whose juices bear the nearest resemblance to the humours of animals; as has long ago been shewn in the instance of mustard.

Of Fewels from fossil Bodies.

1. **W**HAT is still further remarkable, is, that the same law of combustibility holds also in the fossil class; for it has been found that oils are the only parts of these that are inflammable; and again, that among these several oils, the lighter and thinner afford the less smoke, soot, and ashes; and the thicker and heavier the more. Some of these may not improbably be almost as subtile as alcohol; though I do not know that any have yet been found capable of mixing with water.

*Naptha like
alcohol.*

2. We read indeed of a liquor distilling from rocks, which, on the application of a torch will catch fire; and even of the water of some fountains which will do the like; but whether the liquors here kindled be miscible by water, is not mentioned by the relaters. We read in history, that the *Babylonian* naptha was so subtile, volatile, and apt to catch fire, that it frequently kindled by the torches as they were carried along in the night-time, and thus seem'd as if it had burnt of itself, and would sometimes cover the whole streets with a blue, weak, and hardly devouring flame: by which it should seem, that this liquor, by its tenuity and subtilty, comes near to the nature of alcohol; since in that hot climate, 'tis probable, our alcohol, spread after the same manner, might have the same effect; as is confirmed by the above recited experiment, of alcohol under a bell kindling by a candle, and blazing away. But it being difficult to procure this true naptha, we cannot determine any thing precisely concerning it; for as to what is sold among us under the name of naptha, it always comes far short of such inflammability, being at the same time much thicker and heavier than alcohol.

Petroleum.

3. Petroleum, again, however subtile, appears no way comparable either to the naptha of the ancients, or our alcohol; though when this is purified by a suitable distillation, it grows considerably more subtile, and easier to kindle; but even then it still continues oil, and does not become alcohol. —In the mean while, what has been observed of vegetables obtains here likewise; viz. that the purer, lighter, and more subtile any fossil oily combustible matter is, the less smoke, soot, stench, and fæces, and likewise the lighter, purer, and weaker flame it always affords.

4. Other inflammable fossils, wherein any thick ponderous incombustible *Pit-coal.* matter is mixed, always kindle more difficultly, and require a strong blast of wind or bellows to make them burn briskly; but then the fire and flame, which these fossils hereby conceive, is fiercer in proportion, as sufficiently appears in lithanthrax, or pit-coal. Such bodies again afford a gross black smoke, usually of a rank smell; and when collected, a plentiful soot; leaving behind them a great quantity of fix'd insipid ponderous ashes.

5. Lastly, among fossil fewels, there are some composed of a mere com- *Sulphur.* bustible oil, with the addition of a sharp acid salt; such are sulphurs. When the oily combustible part of these is burnt in the fire, the saline, acid, incombustible part, bearing a near resemblance to the oil procured by fire from vitriol, is collected in form of vapour, and being cool'd again is called *spiritus sulphuris per campanam*; which being further separated from the water mix'd with it in burning, and thus brought to its natural degree of purity, is the heaviest of all fluids except mercury, as well as the sharpest and most acrimonious.

6. Hence, again, it easily follows, that sulphur does not catch flame till it be liquified by the fire, and consequently till it be first heated to a great degree: and again, when the flame has seiz'd its inflammable part, then its heavier, acrimonious, and saline part, becoming much agitated and attenuated thereby, begins to boil in the flame, and is hence dissipated around, producing hereby a great increase in the action and violence of the fire, till becoming sufficiently broken and divided by the continuance of this action of the fire, so as to enable it to escape from the fiery vault into the open air, it diffuses a vapour, which powerfully inflames all the parts of animals it can come at, and particularly occasions suffocation. Other bodies also struck by this vapour of burning sulphur, becomes greatly alter'd thereby, but differently according to the different natures, and the relation which they bear to this, which is the most acid of all known bodies. These effects of kindled sulphur are usually mistaken, and attributed to elementary fire, from whence they ought by all means to be distinguished; 'tis certain however, that they are owing partly to the elementary fire, partly to the combustible part of the sulphur, and partly to the acid incombustible matter render'd volatile by the fire. After this we shall not need to give any particular explanations of the manner wherein bitumens, asphaltums, pissasphaltums, or *Jews-pitch* act in the fire, or are acted on by it; which may easily be understood from what has already been deliver'd. It may suffice to observe, that in these there are found fossil fat oils, generally acid salt, also earth, and frequently something metalline and stony; in all which, however, that which properly burns is of the oily kind, tho' the other matters mix'd therewith, afford a sort of spicula, which being vibrated by the fire, increase the force thereof, and enable it to produce extraordinary effects on certain bodies. We have treated sufficiently, with regard to the present design, concerning the nature of the *babulum* of fire; and shall now, from the preceding history, draw a number of corollarics, which we apprehend fully made out thereby.

p

X x

7.

*Fire rarifies
all bodies.*

7. (1) That simple pure elementary fire rarifies all the tribe of bodies, hitherto discoverable by the senses, whether solid or fluid, or compounded of both, by mixing itself therewith.

*This property
peculiar to
fire alone.*

8. (2) That this property is peculiar to fire only; no other known body having yet been found to be possessed thereof: the effervescencies, fermentations, and particular rarifications of bodies, being no sufficient proof of the contrary.

*Fire every
where pre-
sent.*

9. (3) That fire, so far as 'tis known by rarification, is perpetually present in all places, as well in the fullest corporeal space, as in the most perfect vacuum.

*And that e-
qually.*

10. (4) That fire is equably distributed every where, so long as no particular cause arises to collect it, thus dispersed, in some determinate place.

*Collected by
attrition.*

11. (5) That the mutual attrition of certain bodies, is, perhaps, the first and primary collecting cause.

*Has an expan-
sive power.*

12. (6) That fire has a power of moving freely every way, or of thus expanding itself spontaneously.

13. (7) This motion or expansion may however be directed in a parallelism, or by converging lines; which is another, and the most common way of procuring fire.

*Directed by
the sun.*

14. (8) That the sun is manifestly the capital cause, whereby fire, of itself undetermined, is forced into parallelism.

*Cause of the
rays converg-
ing to a focus.*

15. (9) That reflexion or refraction of the collected fiery rays is the cause of their converging in a small space, called a focus; which is another manner of obtaining fire.

*Fire obtain'd
by collision of a
steel and flint.*

16. (10) That a vehement fire is produced in a moment by the quick collision of a cold steel and a cold flint in a cold place and season; which is a fourth manner of obtaining fire.

*Its matter not
supplied by the
sun.*

17. (11) That this fire, with respect to its matter, does in no wise proceed from the sun.

18. (12) That it remains, however, united with bodies a shorter or longer time, in proportion to their less or greater density.

19. (13) That no body, yet found out, is capable of retaining fire for a perpetuity.

20. (14) That the fire we have here described is that universally allow'd to be elementary fire.

Fire fed,

21. (15) 'Tis commonly supposed there is likewise another kind of fire, which consumes combustible bodies into invisible parts, and which is judg'd to be fed, and falsely imagined to change such bodies into true fire: and this is thought to be produced by applying fire to a proper pabulum in the open air: and is the fifth and most usual manner of procuring fire.

By alcohol.

22. (16) Pure alcohol is the only matter yet discovered that nourishes fire so as to be totally consumed thereby; without yielding any thing more than a pure flame, and leaving nothing behind upon its extinction.

23. (17) The force of fire, however, may be increased by a mixture of other bodies with its pabulum; these being agitated therewith by the fire.

24. (18) The kindling a fire does not create or generate fire *de novo*, neither is there any destroy'd by its extinction; fire being unchangeable, and perhaps void of gravity. It should seem, however, that the contrary to this assertion is built on such solid arguments, that after Mr. Boyle gave us his treatise of *the ponderability of flame* (q), it scarce appeared to admit of a doubt; and much less since *Homberg* published his observations on the great additional weight that incombustible bodies receive from the purest elementary fire, quite unmixed with any material fuel: from all which 'tis manifest, that elementary fire is capable of concreting instantaneously with bodies, and considerably augmenting their weight. I proceed therefore, out of the regard I bear to truth, to relate the experiments brought in proof thereof. (1) Mercury, previously well cleansed by metals, and thus render'd more fluid than the native sort, being digested in a clean vessel over the flame of a lamp, for a sufficient time, is changed into a black, white, or red powder, and has its weight increased by the operation. (2) *Du Clos* shew'd before the Academy of Sciences, that a quantity of antimony, exposed to the burning-glass, encreased a sixteenth part in weight, though a large share of it was lost in fumes by the operation. (3) *Homberg*, carrying his enquiries still further into these matters, by experiments made with *Tschirnhaus's* glass, having its focus directed into a hollow vessel, seems to have proved still more clearly the possibility of the union of true fire with bodies, its consequent concretion, and forming therewith a new and very different body, considerably encreased in weight. In this view he exposed four ounces of *regulus antimonii martialis*, reduced to powder, to the focus of the large dioptrical glass of the Duke of Orleans, at the distance of a foot and half from its true focus; stirring it frequently with an iron ladle, till it ceased fuming: a copious thick fume arose in the beginning, and continued for a long time afterwards; and the powder, after the operation, was found to weigh four ounces, three drams, and a few grains; so that it had encreas'd near one tenth of its original weight. This powder being next exposed to the true focus of the glass, and thereby instantly fused, directly lost an eighth part of its original weight, with the three drams and few grains it had gain'd in the former operation: whence it should seem probable, that half an ounce of the regulus was lost in the first calcination; and that the fusion in the second wasted the three drams of fire introduced in the first. And this seems confirmed by the preparations of red-lead, quick-lime, and some other substances in the fire. That such was the event of these, and some experiments of Mr. Boyle, I do not doubt; being equally convinced of the ability of those great men for making experiments, and their candour in relating them. But I must add, that having thoroughly ignited a piece of iron, of eight pounds, it acquired no additional weight; for weighing it in this state, and after leaving it in the scale till it was become cold, the weight thereof in both cases was precisely the same: and yet the degree of heat, or quantity of fire in the iron, considerably exceeded that of the focus above-mentioned in M. *Homberg's* experiment. But as the calcination there was made in an iron ladle, or earthen vessel, and the matter employ'd

X x 2

kept

(q) See Boyle Abr. Vol. II. p. 388.

kept constantly stirring with an iron ladle, the bulk of the powder might hence be increased. The true focus immediately expels the fire, supposed to be united with the antimony; if indeed it may be called real fire. Such an increase of weight, however, does not happen in all bodies thus calcined, but only in those abounding with a rapacious sulphur, as antimony, lead, tin, iron, and orpiment; whence this addition is, perhaps, owing to the corrosion, attrition, and mixture of the particles of the sulphur with those of the other bodies, separated by fusion in such operation. But the encrease of weight, in bodies exposed in glass vessels, from the supposed insinuation of fire into them, is so small, that it may, perhaps, rather be ascribed to something communicated to them from the glass itself. Experiments of this kind should be purposely made, but with great caution, as we may be easily led into error: and that I myself may not seem too peremptory and partial in my opinion, I shall refer you to that accurate relater of experiments, *Du Hamel*; whom you will find after such relations, skilfully raising difficulties against them, requiring further illustration. And you will there meet some experiments of *Boulduc* (r), strongly favouring the contrary opinion (s).

25.

(r) See *Hist. Acad. Scient.* p. 14, 15.

(s) Mr. *Boyle* gives us several experiments to shew, " That fire and flame may incorporate with solid bodies, and increase their weight. Having disposed a quantity of sulphur and a copper-plate in a tall receiver, so as that the plate was at a considerable distance from the sulphur; upon firing the sulphur, and letting it burn away, so that its flame reach'd the metal, the flame seem'd to have actually penetrated it, and to have made it visibly swell, and grow thicker; which appeared to be done by a real accession of substance; since, after he had wiped off some little adhering fordes, and with them several particles of copper, that stuck close to them, the plate was found to weigh near thirty two grains more than at first; and, consequently had increased its former weight above a fifth part.

" Upon a very shallow crucible. we put one ounce of copper-plate, and set it in a cupelling furnace, where it was kept for two hours; and then being taken out, we weigh'd the copper, which had not been melted, (having first blown off all the ashes) and found it had gain'd thirty grains.

" Steel being a metal that, as experience informed me, will very easily be wrought on by fluids of a saline nature, 'twas reasonable to expect, that flame would have a greater operation on it, especially if it were before-hand reduced to small parts, then on any bodies hitherto described. And accor-

" dingly four drams of the filings of steel, being kept two hours on a cupel, under a muffler, acquired one dram, $6\frac{1}{4}$ grains, increase of weight.

" A piece of refined silver being put upon a cupel under a muffler, and kept there for one hour and an half, was taken out and weigh'd again; and as before it weigh'd three drams, $32\frac{1}{4}$ grains, it now weigh'd in the same scales, 3 drams, $34\frac{1}{4}$ grains.

" And to prevent all suspicion of any increase of weight in the metal, arising from smoke, or saline particles, getting in at the mouth of the vessel; I made the experiment in glasses, hermetically sealed, as follows: some tin, which had been before partly calcined in a glass, being melted again in a crucible, we weighed out just eight ounces; and these we put in a bolt-head of white glass, with a neck about twenty inches long; which being hermetically sealed, after the glass had been a while kept over the fire, lest it should break by the rarification of the air, the metal was kept in fusion for one hour and a quarter. Being unwilling to venture the glass any longer, it was taken from the fire, and when it grew cold, the seal'd end was broken off; but before I could have the bottom cut out, I observed that the upper surface of the metal was very darkly coloured, and very irregularly rough; and the lower part had between the bottom, and the under-side of the lump, a pretty deal of loose dark-coloured calx; though

25. (19) It should seem that elementary fire may be increased to so great a degree in a particular place, as to prove the cause of certain physical effects in bodies, otherwise not readily accounted for; but which may now be observed and reduced to a body of natural history. And this is further confirmed by dioptrics and catoptrics, especially when they are both applied, and conspire in the same operation. And the action of this fire is the more remarkable, on account of its being unmixed with any heterogeneous matter, and material fewel; whence we are shewn the force of the action of simple pure elementary fire upon bodies exposed thereto; which, by a nice inquiry, seems reducible to two effects, namely *dissipation* and *vitrification*. (1) It instantly dissipates all such liquors and solids as are volatile in the fire: and, (2) It vitrifies almost all the fixed solids yet known, that are not dissipated thereby. These, we have already frequently observed, are all the effects discoverable in the greatest degree of fire, procurable by all the means hitherto found out for this purpose; but as fire may possibly be collected, and increased to infinite degrees, it would be wrong to imagine that its ultimate possible action upon bodies is determined. On the contrary, the greatest known degree of fire, is but the beginning, as it were, of the greatest degree possibly producible. And since it appears, that the small increase of fire from the extremest cold to the intensest heat, by the union of the foci of *Villette's* and *Tschirnhauser's* glasses, produces so many several and wonderful effects; what folly must it be for a person to conclude, that he has gain'd a complete knowledge of the action of fire on bodies?

26. (20) Again, it appears that elementary fire, being once collected in any place, from whatever cause, may be there preserved by a suitable pabulum; which is always either alcohol, vegetable, fossil, or animal oil: and that such fire, thus supported, may be surprizingly encreased by the additional

Elementary fire may be excessively increased.

How preserved.

" though the neighbouring surface, and some
" places of the lump itself, look'd by candle-
" light of a golden colour. The lump and
" the calx together were weigh'd in the same
" scales carefully, when we found the weight
" to have increased about twenty-three grains;
" though all the calx we could easily separate,
" being weigh'd by itself, amounted to near
" eighty grains.

" We received this further information from
" our experiments, that bodies very spirituous,
" fugitive, and minute, may, by being asso-
" ciated with proper particles, tho' of quite
" another nature, so change their former qua-
" lities, as to be arrested by a solid and pon-
" derous body to that degree, as not to be
" driven away from it by a fire intense e-
" nough to melt, and calcine metals. For the
" foregoing trials seem plainly to discover,
" that even the agitated parts of flame, minute
" enough to pass through the pores of glass
" itself, were some way entangled among the
" metalline particles of tin and lead; and
" thereby brought to be so fixed, as to endure
" the heat that keeps those metals in fusion,

" and gradually reduce them to calces; a
" phenomenon that one would not easily look
" for, especially considering how simple a
" texture that of lead or tin may be, in com-
" parison of the more elaborate structures of
" many other bodies.

" And this phenomenon, which shews us
" what light, and fugitive particles of mat-
" ter may permanently concur to the com-
" position of ponderous and fixed bodies, will
" perhaps afford useful hints to the speculative;
" especially, if this strict combination of a
" spirituous and fugitive substance with such
" as being gross and unwieldy, are less fit
" than organized matter, to entangle or de-
" tain them, be applied, as it may be, with
" advantage, to those aggregates of spirituous
" corpuscles and organical parts, that make
" up the bodies of plants and animals. And
" this hint may suggest a considerable in-
" ference to be drawn from the operation of
" the sun on appropriated subjects; supposing
" it to prove like the flame of tin and lead."

Boyle Abr. Vol. II. p. 388, & seq.

tional gravity of the incumbent atmosphere, and a large supply of oleous sewel, intimately mixed, in a proper quantity, with other heavy matters, and briskly blown with several large bellows, all directed to the same centre of the fire. The ultimate effect of the greatest known degree of such fire, is the production of phosphorus in animals and vegetables, of glass in vegetables, and the fusion of gold in fossils, which undergoes no change therein.

27. (21) Having now explain'd the chief physical ways hitherto known of collecting and preserving fire in any place, it remains to speak of another very powerful and frequent manner of doing the same, *viz.* by the mixtion of different bodies together; in which there occurs a great number of surprising effects and phaenomena: we shall only single out a few.

Of producing Heat by the mixture of vegetable bodies.

1. **N**aturalists have long ago observed, that a considerable heat or cold are sometimes produced, from the mere mixing of certain different bodies intimately together, though there existed no such heat or cold in either of the bodies before mixtion; nor does it continue longer than while they are mixing; which being finished, the new heat or cold cease, and the bodies return to the same temperature, which they had before mixture.

2. This history was first begun by the Lord *Bacon*, and completed by Mr. *Boyle* and Dr. *Hook*: Some articles of it I shall now exhibit; in order to which it may first be necessary to give some account of the instruments, which I shall use therein. ABC is a large thermometer, filled with fine spirit of wine, and fasten'd to a groove in the middle of a board, in such manner, as that the lower part MBA remain at liberty from the wood, that vessels may be the more commodiously placed under the same; on the board EG are mark'd the numbers of the degrees of the ascending and descending liquor, which will be the more visible, if the board be painted black, and the figures white. Lastly, a vessel full of liquor is applied under the instrument in such manner, as that the whole thermometer AB remains within the vessel, in a fluid of the same degree of warmth with the thermometer itself: things being in this situation, and another fluid being poured in, and mix'd by stirring it about with a glass tube, the thermometer will then indicate the change in respect of heat and cold produced by the mixture.

Plate V.
Fig. 1.

EXPERIMENT I.

Heat from
mixing water
and spirit of
wine.

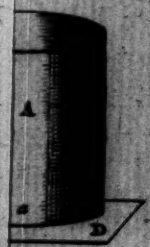
3. Having in one vessel two ounces of rain-water, brought to a great degree of purity by distilling with a slow fire in a tall vessel; and in another vessel the same quantity of common spirit of wine, I examine both fluids by a small thermometer, and find the heat of each of them 44 degrees; then placing one of the vessels under the thermometer above described, which also denotes 44 degrees of heat, I suddenly mix the water and spirit of wine together,
by



Fig. 4.

hermetically sealed
about a third of
meter DC.

or Mercury
Equal Parts



J. M. G. Smith

Plate V. see pag. 342.

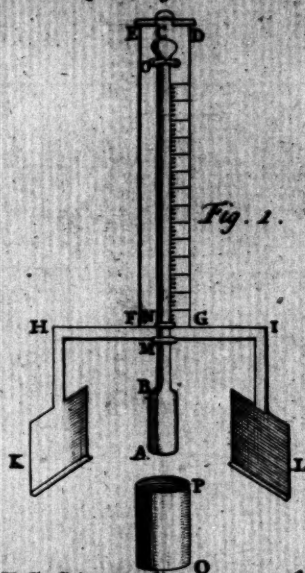


Fig. 1.

ABC A large Thermometer fix'd
in a Frame DEFG by brass Rings MNO.
DEFGHIK L Its Pedestal.
PQ. A Vessel for the Ball.

ABC. Fahrenheit
or Spirit Thermometer.
AB. The Ball.
BC the Stem divided

Plate VI. see pag. 342. 389.

ABCD. a brass Plate hollow at VXYZ to receive the Ball of the Thermometer.

EF. A Mercurial Thermometer showing the greatest natural Cold at I, and the Heat of boiling Mercury at F.

GE The Ball

GF. The Stem, dividable by the brass Plate into 600 equal Parts, but divided here into larger Portions, each containing 60 equal Parts IKLMNOPQRS

GH. Two brass semi-circles to fix the Thermometer at Pleasure, (as examined at c d. a brass Vessel for the Thermometer when a boiling Fluid is to be





Fig. 2.

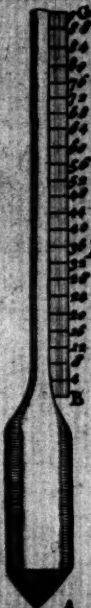


Fig. 3.



Fig. 4.

ABC. Fahrenheit's first or Spirit Thermometer.
AB. The Ball, (equal Parts)
BC the Stem divided into 96

ABC. Fahrenheit's 2^d or Mercurial Thermometer
AB. The Ball, (former)
BC The Stem like the

AB. A Glass Tube hermetically sealed containing Fahrenheit's 3^d or Animal Thermometer DC.
DE The Ball
EG The Stem
ET The Fluid or Mercury
EFG A Scale of equal Parts



Fig. 1.

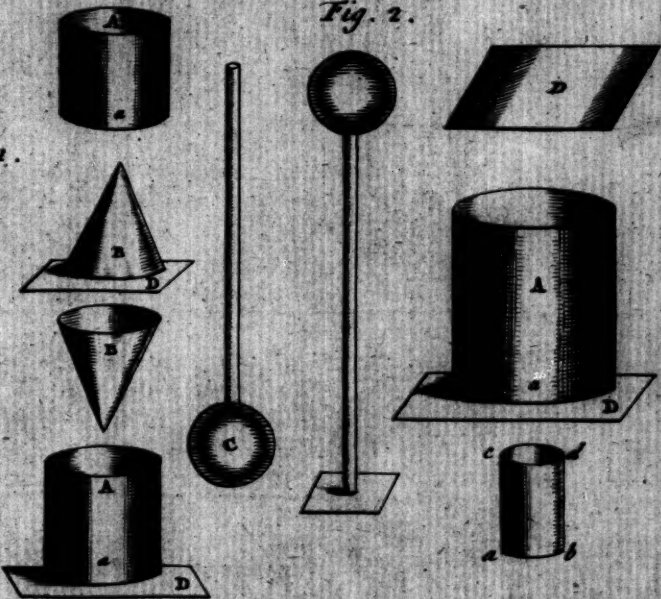
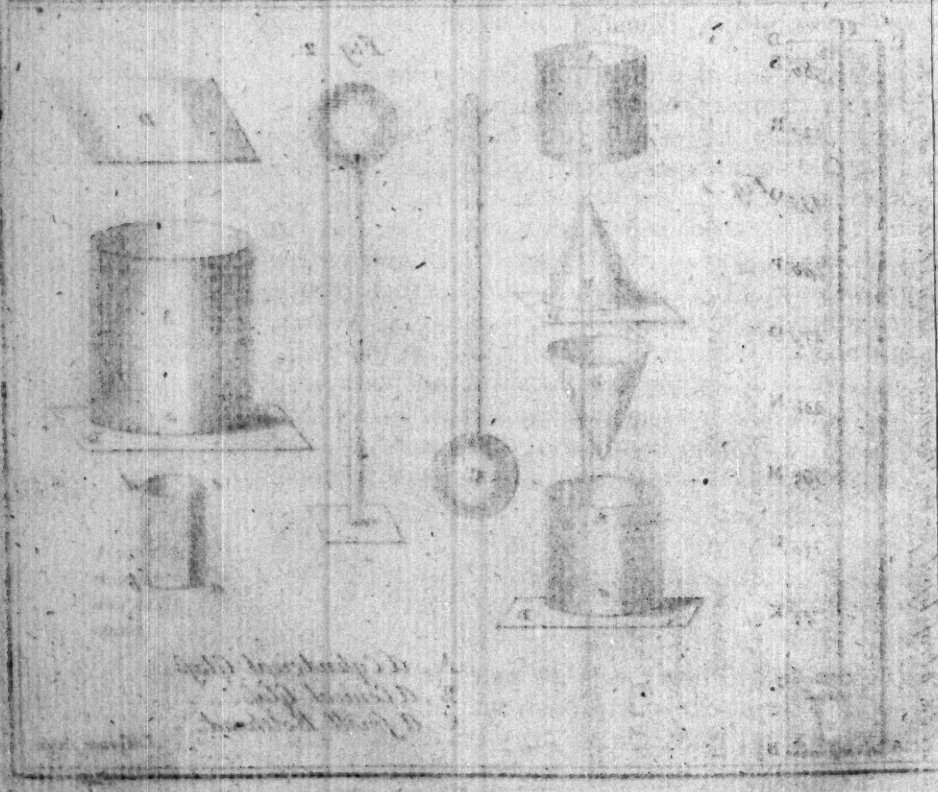
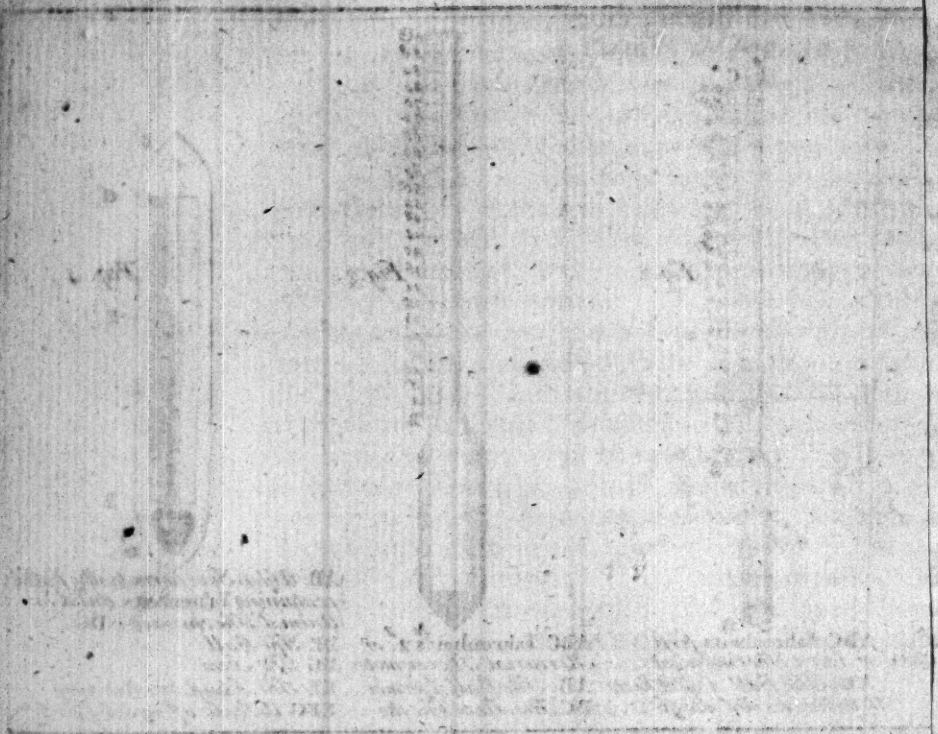


Fig. 2.

A. A Cylindrical Glass.
B. A Conical Glass.
C. A small Bolt-head.

J. M. Smith sculp.



by pouring one into the other, and stirring them about with a glass tube of equal coldness; the result is, that the liquors grow hotter, so that the spirit in the thermometer rises to 52 degrees: whence we learn, 1. That pure water and spirit of wine were equally hot in the air before the mixtion. 2. That the air, spirit of wine and water were equally hot before the mixtion. 3. That air and water, or spirit of wine and air, remain equally hot after mixtion, as before. 4. That water and spirit of wine, when mixed, presently grow hot; and this not from any heat which before pre-existed in them, in regard they were equally hot or cold. 5. But from some physical cause latent in them, and which after mixtion immediately turn'd them hot. 6. That this heat produced by the mixture does not continue longer than the act of mixtion continues; which being compleated, the heat ceases, even tho' we continue stirring more strongly than before. 7. That the whole physical cause therefore of so considerable a heat here produced is the application of the particles of spirit of wine to the particles of water; at the moment of the contact between which fire is produced, which presently disappears again after the contact is compleated. 8. That the fire produced, or render'd manifest by this mixture, is true elementary fire, as appears from its effect on the thermometer. 9. That a considerable quantity of the heat produced must have been lost, before the thermometer could have been heated to such a degree.

EXPERIMENT II.

4. Again, I take two vessels, in one of which is the same quantity of the former water, but heated to 44 degrees, and in the other an equal quantity of pure alcohol, exactly of the same degree of heat as in the former experiment, which is found by the thermometer's noting the same degree: then mixing the two together as before, the thermometer rises to 62 degrees. —Hence, (1) We infer all the same particulars already enumerated in the former experiment. (2) Water and alcohol mix'd together heat much more strongly than water and spirit of wine. (3) The cause therefore of such greater heat depends only on the proportion of the alcohol to the water. (4) Water, when poured on alcohol, occasions a greater degree of heat in the same, than the alcohol had before, notwithstanding its great similitude with fire; for alcohol, if mix'd with alcohol, does not generate any further heat, which water mixed with alcohol does. (5) The less alcohol this water has in it, that is, the purer it is, the greater heat it produces by mixtion with alcohol, and *vice versa*.

EXPERIMENT III.

5. Take two ounces of alcalised alcohol, and as much of the purest water; before mixture they will be found equally cold, viz. in 41 degrees, which is also that of the thermometer; but upon mixing them the heat arises

*The cause of
the heat here
generated,
what.*

to 54 degrees. Hence we learn, (1) The same particular above specified in the first and second experiments. (2) That water and alcalised alcohol, by mixtion, produce a greater degree of heat than water and spirit of wine; but less than water and pure alcohol. (3) That the cause thereof of this increase of heat is in the alcohol and water alone.

6. These may be compared with several experiments of M. *Geaffroy*, which shew a considerable production of heat; in all which, besides what has already been observed, one of the most remarkable things is, that the heat was wholly generated at the moment of the mixtion, and increased not the least afterwards; whence the sooner this was effected, the greater degree of heat was also produced; and the more slowly and successively the mixtion was, the less heat was always produced by the same quantity of ingredients (1). In effect, when once the mixture is compleated, so that the several parts of the water are in contact with those of the alcohol, no further heat is to be expected; for though the mixture be shook with the greatest vehemency, the degree of heat will still remain the same, and even presently after will begin to abate, which it will continue every moment to do, till in a short time it have return'd to the degree of heat found at that time in the external air. — Hence again we learn, (1) That at the point of time when the attraction arises between the particles of the alcohol and the water, the physical cause which collects the heat arises also; but what this should be, may be hard to say; yet thus much is observed, that about the moment when this mixtion is made, the transparency of both fluids is considerably disturbed, and they continue in some measure opaque, so long as the heat here produced continues, and when this is vanished becomes limpid again. At the same time also there arises a great number of small bubbles, which gliding through the mixture quickly break, vanish, and rise again; but after the heat is once produced, we perceive them no longer. Whether these bubbles by their motion produce the heat itself, or whether they themselves are produced by the heat, from the rarification of the aerial particles whilst they are heating, will be difficult to assign.

7. (2) Thus much at least we learn hence, that this heat does not immediately depend on the contract between the united substance of the two ingredient liquors, but rather on some other cause, which itself depends on that first union of the parts. Whence it appears probable, that the whole heat thus produced, only exists a moment of time; which seems very surprizing; gun-powder itself scarce catching flame quicker on the application of a spark, than this heat is produced by the mixtion of two fluids.

8. (3) The nearer we look into these things, the more dubious still we grow about the true cause which here collects the fire; whether it be the reciprocal attraction between the particles, where by approaching they rush violently upon each other, and by such collision agitate the elementary fire: or whether it be the attraction and repulsion immediately succeeding, which produces so instantaneous an attrition as to generate heat; so that when such attrition ceases, all things return to their former rest.

(1) See *Mém. de l'Acad. R. de Scienc.* an. 1723. p. 53.

9. (4) And as this heat arises by mixing of water and alcohol together, whether they had separated this or that degree of heat before the mixture, since a new proportionable increase of heat is always found after the mixing, it follows that alcohol, mixing with the watery part of our blood, may heat it very suddenly to a certain degree, and for a certain time, beyond which it will have no effect.

10. (5) Hence also cold moist bodies may be heated by friction with alcohol; whence we may conceive the effects of baths and fomentations made with alcohol.

EXPERIMENT IV.

11. If we mix pure water with the finest generous wine after the same manner as the former, when the mixtion is compleated, there will be no sensible increase or diminution of heat; some slender, but scarce sensible warmth indeed appears excited. Whence it follows, first, that water and wine, which are equally hot in themselves, continue likewise, after mixtion, of the same degree of heat as before. (2) That the application, therefore, of wine does not of itself heat either more or less than water; consequently the heat imparted to the human body, by drinking wine, does not depend on the heat before existing in the wine, and communicated thereby to the juices, so much as on its stimulus, whereby the velocity of the blood's motion thro' the vessels is increased, and consequently the attrition between the vessels and their contents.

EXPERIMENT V.

12. Water, and strong distill'd vinegar, which before in the air were equally hot, being suddenly mix'd together, produce no new heat, but remain at the same degree as before mixtion.---Whence it follows, (1) That water and vinegar are equally hot, and this either when separate, or mix'd together. (2) That the cooling virtue of vinegar, with regard to the human body, so much celebrated by physicians, must depend on some other cause than the cold naturally inherent in it.

EXPERIMENT VI.

13. Oil of tartar *per deliquium*, and pure water taken in equal quantities in two vessels, are found equally hot with the external air, and after mixing them suddenly and intimately together, they still retain the same degree of heat.---Whence, (1) That liquor, which to us appears the most fiery of all others, is in reality no hotter than pure water; nor is water at all colder than that most heating of all fluids: This might appear a paradox to a person unacquainted with the above experiment; but in reality nothing is truer.

Y y

- (2) The same fiery liquor, when mix'd with water, does not abate any thing of the coldness thereof. (3) A fixed fiery alkali, after being dissolved in a sufficient quantity of water, can raise no further heat in any other water. (4) This alkaline fluid, when mixed with the watery part of the blood, cannot excite any heat therein.

E X P E R I M E N T VII.

*Water and oil
of turpentine,*

14. Water and distill'd oil of turpentine, when separate, are of the same degree of heat with the atmosphere at that time, as appears by examining them with a thermometer; and even when intimately mixed, and vehemently stirred about, there appears not the least addition of heat.—Hence again, (1) An essential distill'd oil, which commonly warms the human body to a degree, and preserves it so powerfully against cold, is in itself, in reality, no hotter than pure cold water. (2) This oil, which in many respects approaches so near the nature of alcohol, yet being mixed with water, adds nothing to its heat; whilst the mixture of alcohol makes so considerable an addition, as above shewn: which further confirms the doctrine above delivered, of the first access and contact of the alcohol and water being the chief cause of the heat there produced. (3) Therefore the admixture of this oil with the humours of our body cannot increase their heat.

E X P E R I M E N T VIII.

*Alcohol and
oil of turpen-
tine.*

15. The surest sign of the perfect purity of alcohol is, when it can be intimately mixed with a distill'd oil by only shaking them together; since the least quantity of water in it, will render such intimate mixtion impossible. 16. Taking a quantity of such alcohol, which in the air is equally hot with another quantity of pure ætherial oil of turpentine, and mixing them together, we find them unite like alcohol with alcohol, without making the least alteration in the degree of heat that each of them had before mixtion, which those acquainted with the former experiments would scarce have expected.—Hence we find, that the particles of alcohol will dissolve and mix with those of oil, almost as perfectly and equally as with those of water, yet without producing any heat thereby; and consequently, that alcohol, when mixed with the oils in our juices, will not increase their heat, though when mixed with the watery part of our blood it may: such new unforeseen events arise in nature from mixing different bodies together.

E X P E R I M E N T IX.

*Distill'd vine-
gar and oil of
turpentine.*

17. Distill'd vinegar and oil of turpentine, when separate, are of the same heat as the air at such time, suppose 44 degrees; but if slowly and gradually mixed together may increase the heat to 45 degrees.—Hence, (1) vinegar and

and oil of turpentine are of equal heat in themselves. (2) But blending them together, produces a further degree of heat. (3) Hence we begin to perceive the power of acids to generate heat with oily bodies, even tho' the acidity be in the smallest quantity; since by M. *Homborg's* observations it appears, that the quantity of true acid found in the strongest vinegar does not exceed an 80th part of the whole (u). (4) Vinegar, therefore, by mixture with our oil, produces some heat. (5) Vinegar differs in this from water.

EXPERIMENT X.

18. Taking the same vinegar and alcohol as in the former case, and finding them, on trial, of the same heat as air, we mix them together, and immediately a sensible heat arises; so that the thermometer mounts, for instance, from 42 degrees, at which it stood before the mixtion, to 52 degrees. — Hence we perceive, (1) That alcohol and vinegar are of equal heat in themselves. (2) That being mixed together they produce a much greater degree of heat. (3) That alcohol grows much hotter, when mixed with vinegar, than with oil. *Vinegar and alcohol.*

EXPERIMENT XI.

19. Oil of tartar *per deliquium*, and oil of turpentine, before mixtion, were each found to have 45 degrees of heat, and after mixtion the thermometer rose to 48 degrees. — Whence, (1) Those two fluids are of equal heat in themselves. (2) Mixing them together, produces a considerable heat. *Oil of tartar and oil of turpentine.*

EXPERIMENT XII.

20. The same vinegar and oil of tartar *per deliquium*, which singly in the air are found equally hot, for instance of 46 degrees, being suddenly and thoroughly mixed, remain exactly in the same degree. In this experiment I made use of three parts of vinegar to one of oil of tartar. — Hence it appears, that the mixture of opposite salts does not produce fire. *Vinegar and oil of tartar.*

EXPERIMENT XIII.

21. Alcohol and oil of tartar *per deliquium* were found of the same heat with the ambient air, and being mixed in equal quantities as intimately as might be, rose from 64 to 68 degrees. *Alcohol and oil of tartar.*

(u) *Mem. Acad. Roy. V. I. p. 52.*

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EXPERIMENT XIV.

*Alcohol and salt
of tartar.*

22. Having some alcohol in a phial of the same heat with the air, viz. 47 degrees, and pouring into it some pure dry fixed alkaline salt of tartar, the thermometer immediately rose to 51 degrees.

EXPERIMENT XV.

*Salt of tartar
and water.*

23. By adding some dry fixed alkaline salt of tartar to three times the quantity of pure water, the thermometer rises from 47 degrees to 57.

EXPERIMENT XVI.

*The same and
vinegar.*

24. Upon mixing some of the same salt of tartar with three times the quantity of vinegar, the thermometer rises from 43 degrees to 49.

EXPERIMENT XVII.

*The same and
oil of turpen-
tine.*

25. By mixing the same salt of tartar with three times the quantity of oil of turpentine, the thermometer rises from 43 degrees to 48.

26. Hence we learn, (1) That the simples procurable from vegetables by chemistry are naturally of the same degree of heat, viz. the same with that of the atmosphere at such time. (2) That some of those above specified contract a further heat at the time of their mixtion; but that this heat does not continue longer than while the mixtion is making; which being once completed, the additional heat disappears, and the mixture returns to the temperature of the air at that time. (3) That this accession of heat therefore does not arise out of the substance of the mixed bodies, but results only from their present union. (4) That alcohol and water are the chief vegetable fluids, which have this power of generating heat. (5) That salt of tartar and water are the principal solid and fluid bodies, which by their mixture together produce the greatest heat. (6) That alcohol and salt of tartar are the next powerful to these. — We proceed now to examine the parts of animals.

Of producing Heat by the mixture of animal and vegetable Substances.

EXPERIMENT I. in various manners.

1. THE fresh urine of a healthy man being kept in the air, soon returns to the temperature thereof; and after this, if it be mixed with an equal quantity of water of the same degree of heat, the thermometer remains at the same height as before.

Experiments upon urine.

If it be mixed with alcohol, the heat will rise from 38 degrees to 49.

Mixed with oil of turpentine, no alteration is produced.

With salt of tartar, it rises from 38 degrees to 39.

With the strongest vinegar, no alteration is perceived.

With spirit of urine, no alteration.

With salt of urine, it sinks two degrees.

With spirit of nitre, it rises from 38 degrees to 43.

With spirit of salt it rises from 39 degrees to 43.

With oil of vitriol, it rises from 39 degrees to 54.

EXPERIMENT II. in different manners.

2. The urine of a healthy man being kept a long time in a close vessel, and hereby much putrefied, is found of the same degree of warmth as the air in that time; and being mixed with an equal quantity of pure water, makes the thermometer sink a little.

Being mixed in the same manner with alcohol, the heat rose from 38 degrees to 45.

With oil of turpentine, no change is perceived.

With salt of tartar, it fell from 38 degrees to 36.

With the strongest vinegar, it rose from 37 to 38.

With spirit of urine, it fell from 38 to 36.

With salt of urine, from 38 to 32.

With spirit of nitre, it rose from 38 to 40.

With spirit of sea-salt, from 38 to 41.

With oil of vitriol, from 38 to 45.

EXPERIMENT III. in various manners.

3. Salt of urine, procured by distillation from fresh urine, without any other addition except sand, being mixed with water, after the manner so often already specified, made the thermometer sink from 40 degrees to 38.

Salt of urine.

With

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With alcohol, it rose from 40 to 41.

With salt of tartar, from 40 to 45.

With the strongest vinegar, it fell from 43 to 41; and with the same vinegar inspissated to half the quantity, from 42 to 44.

With spirit of nitre, from 43 to 60.

EXPERIMENT IV. *in different manners.*

*Spirit of sal
ammoniac
with distill'd
vinegar, &c.*

4. Taking some of the strong volatile alkaline spirit, prepared with equal quantities of sal ammoniac and salt of tartar, and mixing it with an equal quantity of strong spirit of vinegar, the two liquors, which before mixture were equally hot with the ambient air, made the thermometer rise after mixture from 44 degrees to 48.

With the strongest vinegar, inspissated to half the quantity, from 44 degrees to 47½.

With spirit of salt distill'd with bole, and then rectified, from 46 degrees to 64.

With spirit of nitre distill'd with bole, from 46 degrees to 82.

*Of producing Heat by the mixture of fossils.*EXPERIMENT I. *in various manners.*

*Water, salts,
acid spirits,
&c.*

1. **U**PON mixing 3 ounces of pure water, when 47 degrees hot, with one ounce of pure nitre finely powder'd, the thermometer sinks to 36 degrees.

2. Mixing 1 ounce of pure borax with three of pure water, 48 degrees hot, the liquor in the thermometer falls to 45 degrees ½.

3. Mixing 1 ounce of sea-salt with 3 of pure water, 46 degrees hot, the thermometer falls to 43 degrees.

4. Mixing 1 ounce of sal ammoniac with 3 of pure water, 47 degrees hot, the thermometer falls to 28 degrees.

5. Mixing 1 ounce of oil of vitriol unrectified, with 3 of pure water 45 degrees hot, it rises to 60 degrees.

6. Mixing one ounce of oil of vitriol unrectified, with two ounces of pure alcohol 47 degrees hot, it rises to 60 degrees.

7. Mixing 1 ounce of oil of vitriol unrectified, with 3 ounces of distill'd vinegar, 46 degrees hot, it rises to 60 degrees.

8. Ceruse being mixed with weak *aqua fortis*, in the act of ebullition rises from 44 degrees to 57.

9. Tin-filings mixed in *aqua regia*, during the ebullition, raises its heat from 44 to 56. Iron-filings in *aqua regia*, while the ebullition holds, raise it from 44 degrees to 160 degrees.

10. I have made numerous other experiments of this kind, which it might be tedious to recite; but one thing we may observe, that if all the simple bodies, whose histories we have given among the vegetable, animal, or fossil classes, be examined in such order, as that, first, observation be made of the phænomena arising, when by the laws of combination they appear separately in each single class; and then, after the like manner, the simples of each class be mixed together; we might soon arrive at a complete authentic history of the heat arising from the mixture of different bodies (*u*).

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(*u*) "Take some ounces of strong oil of vitriol, and shaking it with three or four times its weight of common water; though both these liquors were cold when put together, yet in their mixture they will immediately grow intensely hot, and continue considerably so for some time.

"By putting a considerable quantity of dry salt of tartar in the palm of my hand, and wetting it well with cold water, there has been a very sensible heat produced in the mixture: and when I have made the trial with a large quantity of the salt and water in a phial, the heat proved very intense, and continued to be sensible for a long time after.

"Tis known that salt-petre being put into common water, produces a sensible coldness therein, as it doth also in many other liquors; but that the same salt, put into a liquor of another constitution, may have a quite different effect, appears by mixing eight ounces of fine salt-petre in powder, with six ounces of oil of vitriol: for here a salt, not only actually cold, but with regard to many other bodies, potentially so, mixed with oil of vitriol, which is sensibly cold too, quickly conceives a considerable degree of heat, whose effects also become visible in the plenty of fumes emitted by the heated mixture. And tho' gun-powder seems to be of a very fiery nature, yet if some ounces of it, reduced to a powder, be thrown into four or five times as much water, it will very manifestly impart a coldness to it, as experience made with, as well as without, a seal'd thermometer, has assured me.

"I have made an experiment, says Mr. Boyle, in which two liquors, whereof one was natural, did, by being several times separated, and rejoin'd without addition, at each conjunction produce a sensible heat. An instance of this kind we have in salt of tartar, from which, after it had been once heated by the affusion of water, we abstracted the liquor without violence of fire, till the salt was again dry; and then put-

ting on water a second time, the same salt grew hot again in the phial, and produced the like heat a third time, and might probably have done it oftner.

"Perhaps the heat may much depend on the particular disposition of the calcined body, which being deprived of its former moisture, and made more porous by the fire, acquires, by means of those igneous effluvia, such a texture, that the water, impelled by its own weight, and the pressure of the atmosphere, is able to get into a multitude of its interstices at once, suddenly dissolve the alcalizate salts it every where meets with; and briskly disjoin the earthy and solid particles that were blended with them, which being exceeding numerous, though each of them perhaps be very minute, and moves but a very little way, yet their multitude makes the confused agitation of the whole aggregate, and of the particles of the water and salt, vehement enough to produce a sensible heat."

And the same that is here shewn of heat, does likewise appear of its opposite, cold.

"Mr. Boyle observes, that a more intense degree of cold may result from a mixture, than was to be found in either of the ingredients a-part; and also that a considerable coldness may be begun between bodies, neither of them actually cold before they were put together. Having brought a glass full of water to such a temper, that its warmth made the spirit of wine in the sealed weather glass manifestly ascend, I took out the thermometer, and laid it in powder'd sal ammoniac, warmed before-hand, whereby the tinged liquor was made to ascend much quicker than just before by the water; and having presently removed the instrument into that liquor again, and poured the warmish sal ammoniac into the same, I found, that within half a minute or less, the spirit of wine begun to subside, and fell above a whole division and a quarter, below the mark at which it stood in the water, before the liquor or salt were warmed. Nor did the spirit in a great while re-ascend

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----- By the way it may be observed, that the experiments which I have here rehearsed, were not made with all the accuracy possible, but many of them too hastily, for fear of prolonging time; besides, that in regard of the great number of my spectators, I found it necessary to make use of large thermometers, which, it is evident by the great bulk of the part immersed in a small quantity of liquor, must make a considerable alteration in the heat or cold produced in the mixture by drawing it to itself, and thus changing the event. The experiments therefore, for these reasons, must not be look'd on as strictly and accurately just. For such as are disposed to repeat them, I would recommend *Fabrenheit's* excellent mercurial thermometer, which I used in the above-mentioned experiment of producing cold by means of sal-ammoniac. This instrument is exceedingly sensible, even of the smallest heat and cold; and can make very little alteration in the liquors to be examined thereby.

" to the height it had when the water was cold.

" We took a small sealed thermometer, whose stem was divided into equal parts by little specks of amel, that sharp liquors might not eat off, nor spoil the marks. The ball of this instrument we put into a slender cylindrical vessel, and more than cover'd it with strong oil of vitriol; and left it there a while to be reduced to the temper of the surrounding liquor; then we cast upon it by degrees sal ammoniac well powder'd, which being soon furiously wrought upon by the menstruum, a seeming effervescence was produced in the conflict, with great noise and much froth, which more than once was ready to run out of the vessel. But for all this seeming ebullition, the mixture, instead of proving hot, did really grow gradually colder, as appeared not only to the touch, but by the descent of the tinged spirit of wine. But pouring this actually cold mixture into three or four times its weight of common water, which was likewise actually cold; this second mixture

" immediately grew so hot, that I could not keep my finger for a minute or two upon the outside of the containing glass.

" To 12 ounces of sal-ammoniac we put, by degrees, an equal weight of water; and whilst the liquor dissolved the salt, and by the action produced a great coldness, we warily poured in 12 ounces of good oil of vitriol; whence a notable degree of heat was quickly produced in the glass, wherein the ingredients were mixed, tho' it seem'd unlikely, that the two liquors, which usually with sal-ammoniac do each produce an intense cold, should, upon acting together, produce the contrary quality.

" In most of the experiments hitherto proposed, cold is regularly produced in a mechanical way; but in some sort of trials, I found the event varied by unobserved circumstances, so that manifest coldness would be sometimes produced by mixing two bodies together, which at another time would upon uniting disclose a manifest heat; and sometimes again, tho' more rarely, would have but a very faint degree of either."

Of producing true Fire in a cold body, by the sole access of the Air.

1. THE unwearied industry of the chemists has been continually discovering new things, unknown to former ages; among which there is nothing more remarkable, setting gun-powder aside, than that a body should be hereby produced, which, though cold, like all other things, when kept close from the air, is no sooner exposed thereto, and its surface brought in immediate contact therewith, than it conceives fire, and breaks into flames; without the mediation of any other body, or without mechanical attrition, or the application of any fire to it. Such bodies are called phosphori, and of such alone we shall here treat, as not including under this name those others which only shine in the dark, without kindling fire. *The invention of phosphori.*

2. In the first place, therefore, the juices of animals, especially when putrefied, and deprived by fire, of all the volatile parts, viz. their volatile salt or oil, leave a sort of coal behind them, which being mixed with three times the quantity of sand, or of charcoal-dust, or with double the quantity of charcoal, and half of alum, and the whole gradually distill'd in a retort made of crucible earth well luted, by an open reverberatory fire, continually increased, till it be raised to the highest pitch, and there continued equably for a long time, the retort being withal so fitted to the furnace, that the mouth of its beak may touch the water in the receiver, which is duly luted on for the purpose; the fire at last, after causing fumes, will raise a ponderous grey matter, which falls in grains to the bottom of the water, is not dissolvable in water, but liquifiable by fire, and capable of being melted thereby into masses under the water. This is that called the phosphorus of *Krafft, Kunkel, and Boyle*; which, if kept in a close vessel under water, and cold, may be preserved good for a long time. But when the air becomes hotter, it may be seen to flash in the dark thro' the water it lies in, and when exposed to an open warm air, will emit light, and if the air become a little hotter, a constant ebullition of the internal parts of phosphorus may be perceived by a microscope, soon after which it kindles, flames, and consumes away, only leaving behind an oil of vitriol, or some other fluid much like it in acidity and weight (γ). --- This therefore is a new and very different method *Animal, or Kunkel's phosphorus. The cause of its burning.*

(γ) Phosphori in general, says M. Lemery may be considered as so many sponges full of fire, or the matter of light, which is so weakly retained therein, and by so slender a hold, that a small external force is sufficient to put it in a condition to exhale in a lucid form, and sometimes even to burn the bodies that come in its way.

It has been above observed, that there is no body, which can be esteemed a magnet

* *Mem de l'Acad. an. 1713.*

with respect to fire, i. e. no body which attracts it by any peculiar virtue, more than other; and yet our author furnishes some considerations on phosphori, which seem to evince the contrary. "That the fourth way of collecting fire, some have observed, is in some measure magnetical. i. e. performed by means of certain bodies, peculiarly disposed to imbibe and retain fire. For that there is some peculiar agreement and attraction

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from any of the former, of producing fire. Is it that the air, which, when a little hotter than usual, is always supposed to be in a state of ebullition, by its frequent shakes and concussions makes an attrition on the phosphorus, agitates its particles, and thus excites, first, a feeble heat, then light, and lastly flame, in a substance before easily moveable, though fixed? 'Tis certain the same matter, in very cold weather, hardly shines, or grows warm, much less kindles, even when exposed to the air; but when once it has catch'd fire, can hardly be extinguished again. By most of its properties, as well as the analysis made of it by deflagration, it appears to come nearest the nature of the purest common sulphur; only it is somewhat softer and more fusible, and more approaching the nature of wax: but differs from both in this, that it boils and kindles by so small a degree of fire (z).

*The black
phosphorus.*

3. There is another more elegant manner of preparing a matter, which upon mere contact with the air, whether hot or cold, shall immediately produce true burning fire. This was first communicated to me in a letter from *Paris*, dated the 6th of *April* 1712, written by the excellent *M. Homberg*, and delivered to me by the noble Lord *Hasberg*, who added several observations

" between fire and certain bodies, is evident,
" among other things, from black bodies,
" which, as already observed, absorb almost
" all the fire that falls on them, whereas other
" bodies reflect a great part of it, and some
" all. Other instances of such agreement we
" have in the phosphorus *Balduini* and the *Bo-*
" *nonian* stone; which when duly prepared have
" all the characters of attractives: thus, being
" immediately exposed in a dark place, they
" do not afford any light; but expose them
" first to the sun a while, and they will then
" shine in the dark, as having imbibed a
" stock of fire, and lodged it in their spon-
" geous substance, to be dispensed again by
" degrees. The like may be said of the
" phosphorus made of human urine, and other
" chemical preparations, which receive such
" a proportion of fire in the preparation, and
" retain it so well in their unctuous substance,
" that it shall keep there, in water, for 20
" years; so as upon the first laying them open
" to the air, to take fire, and exhale in lucid
" fumes; leaving nothing behind but an acid
" malagma, like oil of sulphur *per campanam*,
" or oil of vitriol. Not that we suppose the
" fire fixed and quiescent all the while in the
" body of the phosphorus; for that it has a
" real motion all the while, is evident hence,
" that if you observe it in any dark place, in
" the summer time, you will find it conti-
" nually fulminating and emitting flashes:
" tho' with all this it scarce loses any thing
" of the fire. So that the fire is not fixed in
" the phosphorus, but in a continual undula-
" tory motion."

In the experiment of the phosphorus, we observe, that water acts on the fire contained in the phosphorus; as keeping it in, and preventing its consumption and dissipation. Hence, as soon as the water is taken away, the heat and smoke immediately confess that the fire is breaking out. Add, that air itself does also seem, in some measure, to keep in the fire contained in hot water; and hinder it from escaping so fast as it does *in vacuo*: Thus, heating two equal vessels of water equally, and then putting one of them in a receiver; as you exhaust the air, the water will boil vehemently, and soon become barely lukewarm; while the other remaining in the open air, has neither boiled, nor lost any sensible part of its heat. Something like this is observed in shining wood; for some wood having rotted in the ground, shall shine very briskly when taken out, the fire having been kept in by the contiguous earth: but in a day or two's continuance in the air, it spends all its light, and ceases to shine. 'Tis hard to say how fire should thus be confined by ambient, loose, porous bodies; or by what action such bodies should produce this effect: pressure, one would imagine, should be altogether inadequate, since it has been shewn that fire, by its extreme subtilty, can readily penetrate through all, even the most solid bodies. *s'Gravesand, ibid.*

(z) See *Boyle Abr.* Vol. III. p. 173. seq. *Slave in Phil. Trans.* 1683. p. 1457. *Homberg. in Mem. de Mathem. & Phys.* an. 1692. p. 74, to 80. *Nieuwentijt, p. 520. Hoff- man. Dissert. Chem. Phys.* p. 336.

variations of his own. The same was afterwards render'd easier, and more agreeable, and thus published in the *Journ. des Sçavans*, an. 1716. p. 60. And as, the former ow'd its origin to the curiosity of an alchemist, vainly seeking for the philosopher's stone in urine; so we are obliged for the latter to a person of the same sect, with equal wisdom seeking the philosopher's stone in human ordure. The manner of making it is this. *How made.* Take some soft part of an animal, cut extremely small, or even some juice or excrement thereof, put it in an iron pan over a moderate fire, and keep it stirring with an iron spatula, till it be scorch'd and converted into a black powder. Or take some fine vegetable matter, for instance, the meal or flower of any vegetable, burnt to blackness as before; to one part of which add four times the quantity of crude alum; make the whole into a fine powder, which being put in an iron pan over the fire, should be kept constantly stirring with a spatula, till almost ignited, to prevent its cohering in lumps, as it is apt to do upon the melting of the alum, when it must be broke again, stirr'd about, and accurately mixed with the flower, till at length it emit no more fumes, and the whole appears a fine, dry, black, fixed powder. Put this in a clean dry glass phial with a narrow neck, filling it so high as to leave a third part at the top of the phial empty; then stop the mouth thereof with a loose paper, so as to let the air pass freely through it, and leave room for the fumes to come through the neck; then place the phial in a crucible encompassed on all sides with sand, so as it may not touch any part, either of the bottom or sides of the crucible, but a considerable space be every where left between the two: and the phial must be covered up with sand, so as only to leave a part of it bare, through which to look into the inside, and observe whether or no the matter in it be ignited. In this state the crucible, with the sand and phial, is surrounded with coals kindled slowly, till at length it be well heated on all sides; when the fire is to be raised, till the crucible, sand, glass, and matter in it be all red-hot, in which state they are to be kept for the space of an hour; after this, the fire being still kept up, the orifice of the phial is to be well closed with wax, to prevent any air from entering: Thus the whole being left to cool of its own accord, we at last find in the phial a black dusty coal, formed of the flower and alum. A small quantity being shaken out of the phial into the cold air, immediately catches fire and burns; but so soon as it has once felt the air, loses all its power of kindling thereby. This manner of producing fire appears the most extraordinary of all that have hitherto been discovered; since the matter thus prepared, will preserve its virtue three months, provided the air be carefully kept from it. *And used.* 'Tis certain, in this experiment the fire produces a true animal or vegetable coal, of a most subtile nature, and consequently fittest to catch, cherish, and keep alive the smallest spark of fire, as we have shewn in the preceding history of coal; and this coal, in the experiment before us, is made drier than can be done by any other means, as appears by the whole process: for if the smallest quantity of moisture, even of that little which is lodg'd in the air, come to touch this powder, the experiment will not succeed: It may be added, that all the air is likewise expell'd out of it by the ve-

The cause.

hement of fire; for the phial must be carefully stopped at the time when the fire is at the highest degree that the glass can bear without melting, and consequently has expelled all the air out of its cavity, and out of the matter contained in it: for if the air be suffered by any means to insinuate itself again into the phial, the experiment will fail. At the same time, during so long a calcination, the alum, which seems only a *lapis calcarius*, corroded by oil of vitriol, and converted into the form of salt, becomes intirely deprived of its air, water, and volatile spirit, leaving only a strong oil of vitriol, destitute of water, and fixed in the dry remaining earth: but such bodies being unable to bear dryness, on the first admission of the air grow hot, by reason of the air rushing into the empty spaces with a force which we have already calculated, produce a vehement attrition between the parts thereof, and thus excite fire; which being received in the fine coal above-mentioned, is easily preserved and kept alive. Whether this, or whatever else be the cause of so extraordinary a phænomenon, it appears that a cold body may, by the mere contact of the cold common air, without any assistance of fire, be so kindled as to consume wholly to ashes, and this with as much certainty as could have been done by means of any known fire: and perhaps the experiment last recited, is the only means whereby this may be effected as often as we please. Who then will undertake to assign the limits of the power of fire? What person would have thought thus much possible twenty-five years ago? And who shall foretell what may be discovered in future ages? What would be the consequence, if the glass phial wherein this cold powder is contained, should break, and the powder fall among gun-powder?

Of Fire produced from cold fossils, by means of Water.

*Fire produced
in iron filings
and sulphur.*

1. **I**F fresh filings of iron, free from rust, be strongly ground with an equal quantity of pure sulphur for a long time, till the whole be formed into a fine powder; the mixture, if kept in a dry air, will continue cold for the longest space, if all moisture be kept from it: but if this powder be only wrought up with as much fair water as will form it into a stiff paste, the mass will soon grow warm, swell, heat, emit a thick smoke, and at length a sulphurous fire and flame; and after the operation is over, there remains a fine blackish calx, which by the affusion of water produces a kind of vitriol of iron, much like the common *vitriolum Martis*, made with oil of vitriol. If a large quantity of each of these ingredients be taken, *e. gr.* twenty-five pounds of iron, and as much sulphur, and the mass thence formed, as before, be buried a foot deep under ground; in about eight hours time the ground will begin to heave and swell, emit hot sulphurous steams, and at length burst out into live flames; thus forming a true vulcano (*a*). For, sulphur being an inflammable oil united with the acid oil of vitriol, and iron a metal always soluble in the acid of vitriol, and producing an intense heat therein; it appears, that when these two are ground

Whence.

(a) See *Hist. Acad. Roy. an.* 1700. p. 52. & *Mem.* p. 101.

fine, and thus come into a number of close multiplied contacts, and bound still closer together by means of water, the acid of the sulphur begins to corrode and act on the iron, and thus excites the usual heat; which increasing every moment, the dissolution itself becomes continually increased; and by the dissolution the heat is raised still further, till at length there arises a flame, partly from the oily part of the sulphur, being now freed from the acid, which is absorbed by the iron, and partly from the vapour of the iron dissolved by the acid oil of sulphur, which is exceedingly inflammable, as Dr. Hoffman has shewn by an elegant experiment (b). For mixing three ounces of oil of vitriol with twelve ounces of water, in a glass phial, whose neck was cut off, and keeping the whole in a moderate degree of warmth, and casting into it at different times an ounce or half an ounce of iron-filings, he found a white vapour arose out of the neck of the phial, which emitted a sulphurous garlick smell, and upon the application of a candle took fire like a flash of lightning; and catching within the phial, and being there violently repelled, produced very surprising effects: whence it appears, that the matter which forms these fumes, is much like that which the fire raises from alcohol. Hence was discovered a new way of exciting fire from a cold uninflamable substance by means of water; and no doubt there are infinite other hidden ways in nature, by which the same effect might be produced, and which may probably be discovered hereafter. Moist hay thrown into heaps, does the same.

Of the production of Fire by the mixture of cold Liquors.

1. **T**AKING half a pound of pure dry nitre reduced to powder, putting it in a pure dry retort, and mixing with it an equal quantity of pure oil of vitriol well rectified, and distilling the mixture in a moderate sand-heat, it will yield a liquor in form of a yellowish fume, which being caught in a clean dry receiver, is the *spiritus nitri Glauberianus*. If now to a drachm of distill'd oil of cloves, saffaphras, turpentine, or caraways, contain'd in a glass vessel, be added an equal quantity, or half as much more of the *spiritus nitri* above-mentioned, a violent flame will arise, however cold the bodies were before the mixtion: an experiment doubtless of infinite use in chemistry, where from two cold liquors, in an instant of time, so rapid a flame is produced as consumes both the liquors, leaving only a little resinous matter, instead of ashes, at the bottom. Hence again we observe, that an acid matter mixed with oily ones, abounding with the *spiritus rector*, constitute a substance much like sulphur, since it readily kindles (c).

2. From a careful consideration of what has been above laid down, we may perhaps be enabled to assert divers things concerning the nature of fire. First then it appears, that true elementary fire is corporeal; since

(b) *Diff. Phys.* cap. 169.

(c) See Borrich, *Act. Hafn.* 167. Hoffman.

Obs. Phys. Chem. 38 to 22, 123 to 127. *Slare*

Philos. Trans. No 150. p. 291.

Because extended.

under the name corporeal is included any thing geometrically measurable by three lines, drawn perpendicularly to each other from the same centre; or, as we more usually express it, an extended surface. Accordingly, all that has hitherto occurred to us, under the denomination of fire in this discourse, was always extended. For suppose a solid silver globe suspended by a thread, and almost ignited, let it fall gently into cold water, without making any considerable shake or agitation therein, the fire will distribute itself through the measurable spaces of such water, heating those most which are nearest the globe, and all the rest in proportion, and thus truly extends itself: And if thermometers be placed in the same water at different distances from the globe, they will indicate different degrees of fire diffused through the body and space of the water; which shews, that there is a true mixture between fire and body, or space; and consequently a true extension. In effect, the whole history of fire evidently proves, that fire is extended as truly as body or space itself.

And moveable or quiescent.

3. Another general property inseparable from bodies, is, that they may exist successively in the place which is next contiguous to that they already possess, and thus may truly be moved, whether they remain in the same space, and only revolve round an axis, so that all the parts continue in the same place, though none of them singly remain in the same place which it had before; or whether the whole mass, consisting of all the parts united together, quit its former space, and remove into that adjoining, and thus continue to do for some time: or lastly, whether both these happen together. Now that fire is moved after this manner, abundantly appears from all experiments; there being none wherein fire is not found to have a true physical motion: and as mobility is so strongly connected with a power of resting in bodies, it cannot well be denied, but that a body which exists one moment in any given space, might continue in the same for two moments, which makes what we call rest: and as all the actions of fire, which are performed by motion, may still be increased or diminished, it appears in no wise absurd to hold, that fire may also rest in a certain place, as well as all other bodies.

Resists bodies.

4. A third property peculiar to body is, that a solid body, considered as such, when subsisting in a certain place, resists with an infinite force any other body from existing in the same space at the same time with it. This some call resistance or impenetrability: *Democritus*, by a very significant term, calls it ἀντιστάσις, or repercussion, which expresses the former; for we suppose nothing more is meant by the word impenetrability, than that a body, tending into a space already possessed by another, is repelled from it; which repercussion, if it be found in any body, certainly is in fire, which moves, changes, and fashions even the most solid matters, so that none has hitherto been found which is not changeable, even in its solid nature, by fire; and likewise moveable by it, so as to be carried into other places, by the impetus which it hence acquires. If we further consider, that pure elementary fire, when acting upon given bodies, is repelled and reflected by the same with a vehement force, capable of moving all other things, we shall be sufficiently convinced of the true ἀντιστάσις, of fire, and consequently

quently of its corporeal nature. For if the rays of fire determined by the sun, fall on the cold, and therefore elastic or repercussive speculum of *M. Villette*, they will be reflected in a quantity, which may almost be computed proportionably to the aperture of the speculum, into a focus; where they will exert their corporeal action in a violent degree: which sufficiently shews, that fire moves with a power of resisting. But the argument will be still more confirmed, if we consider, that if the speculum were first heated, and so dilated, made laxer, and less elastic, and consequently less vibrative and repercussive; the same rays of fire, in their reflexion from the speculum, will come exactly with so much less force into the focus, as the speculum is now less hard than before: from whence it evidently appears, that fire is truly corporeal and resistable, since it is repelled from a body it strikes against. It may be added on this head, that if the rays of fire be collected closely together, and thus rendered extremely powerful, so as to be able to melt the metalline part of the speculum, no reflexion will arise; but the fire, by the superiority of its force to the speculum, will destroy the same: a clear proof that this reception is performed by a mere repercussion of one body against another. Nor must it be omitted, that this pure elementary fire, if directed by the sun, through the burning-glass of *M. Tschirnhaus*, so as to fall on the iron needle of a mariner's compass, in the very point of the focus or contact, it will drive the needle round on its pivot by a true corporeal percussion: from whence it appears, that the fire was not penetrable, but truly resistable. Elementary fire, therefore, must be truly corporeal, and consequently every particle of it must consist of other lesser parts united together, but so strongly united, as that we have no reason to think there is any power in nature capable of dividing them. And hence again it appears probable, that the figures of those particles are not changeable by any natural power; so that the element of fire appears immutable in itself, and the great instrument or means of changing all other things.

5. But whether fire have also that further property, which some of the greatest men of the present age hold inseparable from all bodies, *viz.* weight or gravity, in proportion to its solidity, does not so certainly appear from the consideration of the whole history of fire. I am rather induced to believe, that it has no more tendency to the centre of the earth than to any other point; that it has no natural or spontaneous determination at all; that it may be determined any way; that it is present every where, unless hinder'd by some foreign cause, through the whole universe; that of itself it is every where in the same quantity, and acts with the same force: all which particulars, unless I am much deceived, have been proved by the preceding experiments.

6. The particles of fire, which have already been shewn to be corporeal, appear further to be the smallest of all the bodies yet known: for if they be corporeal, they must necessarily be exceedingly subtile, as they readily penetrate all, even the densest bodies, and pervading the thickest parts thereof, shew themselves present in every assignable part thereof. Thus, if a large globe be made of solid gold, and laid on the fire for a due time, it may be so penetrated thereby, as to become ignited to its very centre; so that if it were then divided into two hemispheres, we should find on every point

Is without gravity, and free to move every way.

Consists of the smallest particles.

point in the inside both light and heat, and the other properties and powers of fire. So small then are the particles of this body, that there is no known body so compact and void of pores, so entirely filled to its own bulk, as not to admit and transmit fire. All other bodies hitherto discovered may be excluded from entering the vacuities of others. Thus air, water, spirits, salts, oils, and other things may easily be hinder'd from entering a glass phial hermetically seal'd; and when they are in, may as easily be hinder'd from going out again; only fire has free ingress and egress, and hence produces its peculiar effects. The cause of gravity and the power of magnetism, it must be own'd, will pass through all bodies, yet still preserve their native properties and effects; but we are not certain whether they do this by any particles issuing from them, or in any other manner unknown: and it may be added, that the cause of gravity, and magnetism pervade bodies instantaneously, without any diminution of their powers; while fire requires some space of time before it can penetrate the densest bodies: but hence the corporeity appears more evidently in fire, and less so in them. Hence we have observed, that the particles of fire are the least of all those commonly allow'd for true bodies; since we cannot say whether there may not have been created some corpuscles, which are less than those of fire; but thus much we may affirm, that no physical effects have hitherto occur'd to the senses of mankind, from whence they might be forced to infer, that there are bodies smaller than fire. This their extreme subtilty may also be conceived hence, that gold is so solid, that when a grain of it is drawn over a quantity of silver, so as the thickness of the skin of gold is only $\frac{1}{103000}$ of a 12th part of an inch, yet the best microscope cannot discover the least pore in so thin a leaf (*d*). Nay, if the thinnest leaf-gold be oppos'd to the sun, when shining into a dark room, the rays of light will not be able clearly to pervade it, but only shew a little greenishness through it; and yet a large sphere of solid gold may be penetrated through its matter, however dense, and its bulk however large, by the greatest, as well as by the least fire. For if so large a globe be long expos'd to the cold air in the coldest season, it will assume that temperature, or receive that degree of fire, which is found at that time in the air; and if it be then committed to a strong fire till it become glowing hot, and ready to melt, it has then doubtless a vehement degree of fire in all its parts; yet all this fire will vanish again out of the globe, which in a short time returns to the temperature of the common air. Hence again it follows, that the small quantity of fire found in the thin, fluid air, may equally insinuate itself into all the pores of gold, as the largest and fiercest fire. But if the pores were so very small in so thin a leaf of gold, what must we think of those when so large a mass of solid gold is penetrated through its whole substance by fire. To grow warm and cool again, is doubtless to receive fire in a greater or a less quantity. Thus much might suffice to shew the great subtilty of fire, which yet would appear to be a thousand times more subtle, if it be true that the matter of light and colours is the same with that of fire; for if a chamber be made perfectly dark, with only a little aperture in one single

(*d*) *Mem. Acad. Roy.* 1713. p. 10.

single part, and a good eye, which has been for some time in the dark, be applied on the dark side of the room to the aperture, it will see very distinctly all the external objects, by so many definite distinct rays of fire, reflected from the several visible points of so many different objects, and propagated thence without confusion through the little aperture. If we now consider what a multitude of visible points are here seen in the whole hemisphere, each of which however can only be seen by its own rays, it will give us an idea of subtilty scarce to be conceived. But if a white paper be applied, at a proper distance, in the same chamber, and the rays be transmitted by a convex glass upon it, all the external objects will be painted pretty large, and perfectly distinct thereon; consequently all those rays, and, from the supposition above, all that immense quantity of fire reflected by such a multitude of objects, could be contracted within the narrow space of that aperture: this shews, that the particles of fire, with respect to our imagination, are of an infinite degree of subtilty.

7. The small particles which constitute the ultimate elements of fire, *The most solid.* appear to be the most solid of all bodies: where, by the word solidity, we mean an extended thing which resists infinitely; and by space, an extended thing, which admits and transmits solid matters; so that an absolute solid would be an extended thing, in which there is no penetrable space, but which is every where equally impenetrable in all its points: and if any extended substance be constituted partly of particles thus solid, but so connected together as to leave empty spaces between them; it will follow that such body is partly composed of body, and partly of empty space. Hence also it will appear, that the ultimate elements, or particles of all bodies, must be perfectly solid; but that when these elements are compounded into a mass, there arise vacuities between the particles thus joined together, by their not every where touching each other: whence a mass thus composed will always be full of pores, and consequently less solid than those ultimate elements, separately taken, of which it was composed; and on this account such particles will be more easy to be separated from each other, that is, to be divided. Again, in those last and least particles there should seem to be no pores; and consequently that they are not divisible by any other bodies, but must always remain the same. It being shewn therefore, that fire consists of the minutest particles; it follows, that these can have none, or at least the fewest pores, but all their molecules must be extremely solid. And as impenetrable substance is corporeal substance itself, 'tis probable that all truly corporeal substance, considered as such, coheres with an infinite force, not to be separated by any power; but a mass composed of such matter, with vacuities interspersed among it, will be so far only divisible as it includes empty pores. Fire, therefore, according to this doctrine, must be all corporeal, immutable, incapable of any alteration of figure, and unable either to join and grow to itself, or to other bodies; and in the mean while must have the greatest power of dividing all other things, as it can always enter the pores of bodies to be divided, and exert its power therein, so as to break and dissolve their parts and branches, and thus reduce their composition to its simple elements; or so dispose the elementary particles, as that

it may pass equably thro' all the pores in any direction; as we find in gold melted by the fire, which afterwards becomes incapable of being any further changed thereby. But if this subtle and solid fire be applied to the absolutely solid particles of other bodies, it does not appear that it can make any change therein; but only move their whole mass with some mechanical impulse or attraction, beyond which it can do nothing; which is confirm'd by all experiments. On account therefore of this property, fire may be laid down as the great changer of all things in the universe, whilst itself remains wholly unchangeable.

*The most
smooth.*

8. These corporeal, solid, subtle particles appear perfectly smooth, even, and polished on their surfaces; we mean they have no eminencies or sinkings in any point of their whole circumference: for if any of their extremities were rough or uneven, such places being more exposed to the shock and attrition of other bodies than the rest of the mass, it would follow, that in all actions of the fire, either on its own particles, or on other bodies, the greatest impetus would always be given to those particles which cohere least to the whole; by which means those particles must be continually breaking off from the rest of the mass: so that there would be a continual change of the particles of fire, and consequently of the fire itself; which is contrary to what has been already proved. The utmost solidity of fire, therefore, seems to tend to such a figure, as that all the parts become equally distant from a central point within the same; since by this means they acquire a figure which is least liable to be changed, and makes the greatest resistance to being transposed. If, again, we consider that extreme penetrability, whereby fire passes in any direction through all the pores of any body, it will seem necessary, that the surface of its particles have the greatest facility for passing without impediment; which they could not well do, if beset with hooks or points, or any thing downy and woolly. And since the rays of fire are transmitted so readily, so copiously, distinctly, and freely thro' a small aperture in a dark chamber; it sufficiently appears, how very smooth and equable their surfaces must be in all the points of contact, to prevent their hanging to one another. Add, that the quick reflection and refraction, which is always found in the particles of light, and which answers so exactly to the effect of a spherical figure, is a further indication, that the particles of pure fire are of that figure. From the whole we may venture to collect, that the ultimate particles of pure fire are polished spherules.

*The most
simplest.*

9. From the whole history of fire we may infer its absolute simplicity, by which we mean that condition of a body, whereby each particle of it retains the same nature which is observed in the whole; so that the simplicity of fire denotes such a disposition, as that each of its single particles, should consist altogether of body without any pores; otherwise all the component particles would scarce be alike; and further, that they probably are solid spherules, the whole congeries of which may thus be the same. It may be added, that the simplicity of fire appears chiefly dependant on this, that there being no corpuscles in nature smaller than of fire, it cannot in any wise be compounded of other lesser heterogeneous parts. In effect, the
utmost

utmost smallness must be acknowledged for simplicity; their absolute solidity supposes as much, and their spherical figure abundantly denotes it; so that fire may be put down as the most simple of all bodies existing. Yet it must be own'd the doctrine of the great Sir *Isaac Newton* overthrows the absolute simplicity of fire; a philosopher whose subtle and penetrating genius seems to have surpassed the limits prescribed to human understanding; and who by a most artful anatomy, from a single ray of light procures seven several ones, very different not only in their primitive colours, but in their reflection and refraction: and yet how fine and simple must that single ray have been? If then, after the nature of fire and light had been with so much labour examined, for so many ages, in so many countries, and after so many different manners, a single person could arise in our age, and make such discoveries, who shall assign any limits to the discoveries of future ages in natural things? Who knows what additions may hereafter be made to the discoveries of *Newton*? 'Tis but half an age since all philosophers consider'd a single ray of light, as so exceedingly slender, that in respect of thickness, they unanimously pronounced it indivisible; yet this prince of geometricians has, by invincible experiments and arguments, shewn, that such a single ray is a fasciculus made of seven very different rays, which may be join'd to each other lengthwise, and again be parted from each other, so as to form seven fine threads of different colours, which before made but one apparent thread; and who knows but when dioptrical glasses come to be further improved, and other means and instruments brought to a greater degree of perfection, something like composition may be found even in the simplest rays discovered by *Newton*? We are struck with admiration, when, from these instances, we see what powers the Creator has given to the human mind; whereby, when duly cultivated, we can discover the laws he established in framing the world. Certainly we owe the greatest veneration and thanks giving to that Being, which impressing his own image on our minds, gave us a disposition to understand, study, and love the truth. Yet is not this all the diversity found in a simple particle of fire; the same *Newton* having, in the different sides of one of these simplest rays, discover'd a further diversity.

10. By the refraction of *Island*-crystal, it appears, that there is a different power found on one side of a ray from that found on the other: and as in one magnet with respect to another, the same pole is either attracting or repelling; so in the same ray we find a like power, with respect to the transparent medium it falls on. From the whole it appears, that fire, however simple, contains the following diversities already discovered. (1) With respect to colour, it contains seven different primitive ones. (2) With respect to reflecting and refracting bodies, the rays act differently according to the colours they are of (e). And (3) that this diversity in the sides

(e) Every sort of ray, as it is more or less inflected by refraction, has a particular colour. The rays, *e. gr.* least bent by refraction, are red; those next, orange; then yellow, green, blue, purple, and violet; which

last are the most refrangible. And such colour of any ray is absolutely unchangeable by any refractions, reflections, separations, mixtures, &c.

The reflection of the rays, Sir *J. Newton* shews,
A a a z

sides of the rays appears in a more extraordinary manner in their passing thro' *Island-crystal* (*f*); such a manifold diversity is conceal'd in the simplest of all bodies! What then may we suppose in the more compound kinds? The smaller every where hold forth an image or resemblance of the larger. And were it not for the discovery made by Sir *Is. Newton*, we should have believ'd that the particles of fire are the minutest possible, and perfectly simple: but now though we allow fire the simplest of all known bodies, we cannot deny but that a great diversity obtains in it.

*Always move-
able.*

11. The sixth property of fire is its mobility; which is so great, that we are almost certain it never absolutely rests in any place: nor do we here only speak of that motion, which is always found to obtain in all bodies; for it is certain,

shews, does not arise from their striking on the solid impervious particles of bodies: such reflected rays, tho' they approach infinitely near the body, never touch it; for all those which do touch, are lost and extinguished in the body. The power by which the particles are reflected, is not the immediate resistance of any particles struck upon; but a power equally diffused throughout the whole surface of the body, whereby it acts on light, either attracting or repelling it without contact: which power is the same with that whereby, in other circumstances, the rays are refracted: and by which also they are first emitted from the luminous body.

And hence it is, that where light passes without refraction, there it also passes without reflection; that where the refraction is strongest, there the reflection is so likewise; that light, passing out of a denser into a rarer medium, is more copiously reflected, than in passing from a rarer into a denser; and the reflection is the greater, as the difference of density in the mediums is greater. Add, that every ray of light, in its passage through any refracting surface, is observed to be put into a certain transient state, which returns at equal intervals, whereby it is disposed to be now easily refracted, and then easily reflected. These alternate fits of easy reflection, and easy transmission, Sir *Isaac* accounts for, from the vibrations of a fine, subtle, æthereal, elastic medium; vastly finer and more elastic than air, which penetrates through all bodies, and is diffused through all space. The rays of light, by their attractive powers, or some other force, excite vibrations in this medium; which vibrations being swifter than the rays, overtake them successively, and agitate them so as by turns to increase and decrease their velocities, and thereby put them into those fits.

(*f*) *Island crystal* is a transparent, fissile stone, of the nature of talc: a piece hereof being laid on a book, every letter seen thro' it, will appear double; by means of a double re-

fraction which it makes of the visual rays in passing through it: And a ray of light falling on its surface, in any direction, becomes divided into two rays from the same cause. Now one of these refractions is performed according to the usual rule of optics; *i. e.* the sine of incidence out of air into the crystal, is to the sine of refraction as five to three: But the other, called the unusual refraction, observes another rule; and the ray, which by the first surface of the crystal was refracted after the usual manner, upon passing the second surface, is also refracted: so that both emerge out of the second surface parallel to the incident beam: And the same will hold, if the rays pass thro' several pieces of *Island-crystal* placed parallel to each other; the ray refracted after the unusual manner in the first surface of the first, being found to persist in the same way, in all the surfaces of the rest.

Hence Sir *Is. Newton* gathers, that there is an original difference in the rays of light; by means of which, some are constantly disposed to be refracted after the usual, and some after the unusual manner; for if the difference were not original, but arose from some new modification, which the rays underwent at their first refraction, it would be alter'd by new modifications in the following refractions. And this may give us a suspicion of more original properties in light, than have yet been discovered.

In effect, the rays of light appear to have several sides, endued with several original properties; for the two rays, thus differently circumstanced, are not of different natures, so as that one in all positions of the crystal will be refracted after the one, and the other, after the other manner: all the difference between them consists in the different position of the sides of the ray to the planes of perpendicular refraction: And the same ray, in this or that position of its sides to the crystal, will be refracted either in the usual or the unusual manner. *Newton Optic.*

tain, there is no body in all nature, that ever absolutely is at rest for one moment; the sun, planets, and comets, and the several atmospheres which gravitate along with them, are all continually revolving with rapid motions; and we know of no bodies besides these: nothing therefore is ever at rest, but all things are in a constant vehement motion. Such was the pleasure of the Creator of all things. But besides this, there is another perpetual motion of agility peculiar to fire, as may be shewn from undeniable proofs. Suppose water left to cool till it fall to 33 degrees; which is the utmost pitch of cold that water admits of, since if it go a little beyond this, it can no longer remain water, but is converted into a sort of glass, very brittle and transparent, but liable, by 33 degrees of heat, of being again melted to water; while genuine glass requires upwards of 600 degrees of heat to reduce it to the same state of fluidity: it follows, therefore, that water only becomes water, by virtue of the motion of the fire lodged in it; and that water is not water of its own nature, consider'd separately and independant of fire. The same holds of glass also, of fossils, sulphurs, semi-metals, metals, and perhaps all other bodies; which under a certain lesser degree of fire appear in form of hard bodies, as we have just observed in ice; but upon increasing the degree of heat to a certain pitch, which will be different according to their different natures, they all readily melt, and are converted into a kind of running water. Since then it has been shewn by M. *Fahrenheit's* experiments, that there are still 32 degrees of heat below the point of freezing; it follows, that in all those different degrees the fire is still either in a greater or less motion, and never entirely at rest; not even at those times when all animals and vegetables perish with cold. But it has been shewn by the same experiments, that such degree of fire may still be lessen'd by art 40 degrees more, which proves, that in the greatest natural degree of cold possible, the fire has still 40 degrees of motion more than in such artificial cold; and in the whole interval between the two, it still dissolves some bodies, which by a less degree of heat cohere again into solids; as appears by all the experiments there recited. Fire, therefore, is constantly moving, even in the utmost degree of cold; and in all the degrees of heat therefrom, it moves still more and more. The great velocity of fire, when emitted from the sun to the *Satellites* of *Jupiter*, and reflected thence to our earth, was discovered by a very subtle method, from a multitude of sure astronomical observations continued for ten years, by M. *Roemer*, and communicated in a letter to M. *Huygens*; from which this last author fully demonstrated, that the velocity wherewith fire is propagated, is such as carries it upward of 1100000000 feet in a second (g). Hence it appears, that the velocity must have been very great in this fire or light emitted by the sun, which is allow'd for true elementary fire; if such light be supposed to have proceeded from the sun to such *Satellites*, and thence directed to us as is held in Sir *Isaac Newton's* system: or if, according to the doctrine of others, those spaces be full of matter, it will follow, that such action of the luminous fire could not be communicated so swiftly. But those great astronomers *Cassini* and *Maraldi* have since with infinite pains, by a series of accurate

(g) *Vid. Huygen. de Lum. p. 8, 9.*

accurate observations of many years, carefully compared together, discover'd that this system of *Roemer* and *Huygens*, is far from strict truth (*b*). So that nothing certain can be inferr'd concerning the velocity of light from this principle: thus much, however, we are certain of, that this propagation of light is always the more swift, as it is less successive.

Are not generative of fire.

11. From the same history we may also deduce, that this elementary fire makes numerous alterations in all bodies exposed to it, though it does not appear by any experiment that it alters them so as to turn bodies, which before were not fire, into true elementary fire: from whence again, it does not hitherto appear, that fire has any power of multiplying itself by converting its fuel or other bodies into true fire, and assimilating them to itself.

Nor generable.

12. The more we every day consider the effects of true fire, the less reason we find for concluding any such power in fire, or such disposition in other bodies: from whence again it evidently follows, that if fire be unable to generate fire out of any other matters, neither can fire itself be generated out of any other matters; for what can by any action produce fire out of a body which was not fiery, if fire itself cannot do it? No other thing in nature should seem to bid half so fair for such power, as that universal mover from whence all other things derive their motion, at least all fluids, and probably most solids, and which can neither be produced nor resuscitated, but only made visible where it did not appear before.

But always the same.

13. All these things being sufficiently evident, we may venture to assert, that this elementary fire is always and every where the same in all hot bodies, after what manner soever it were produced therein, with whatever fuel nourished, or by whatever artifice kept alive. It is a false complaint therefore of the generality of chemists, that they want pure fire to use in their subtlest operations, wherein they imagine a most pure astral, celestial, solar, elementary, incorruptible fire required: such needless solicitude they have fallen into through inattention to what we have above shewn. For the heat produced in the bodies either of animals, vegetables, or fossils, always arises from the same fire, and when it has penetrated through glass into the cavity of a vessel, is equally pure, and in all respects the same, as if the vessel had been exposed to the pure rays of the brightest sun: so the heat of burning alcohol and of pit-coal, acting on a matter contain'd in a pure glass hermetically sealed, provided the degree of heat and the manner of application be the same in both, will always have the same effects; and even the fire produced by the putrefaction of the most fetid bodies, after it has passed through a thick glass, becomes as pure and simple, as if emitted from the clearest sun into the same glass: and thus the heat produced by fermentation, putrefaction of animal dungs, &c. is of the same quality as fire. Nor do we find any difference as to chemical operations between the heat of horse-dung, and that of any other heat in the same degree; it follows, therefore, that there is but one kind of fire in all nature, and that elementary and artificial fire are always the same. But this is not to be understood of subterraneous fires, in regard all other kinds of bodies are found floating herein, which mingling with the fire, and undergoing certain changes thereby,

(*b*) *Mem. Acad. Roy. 1707. Hist. p. 77. & Mem. p. 25.*

thereby, have different effects, and make different changes in bodies, exposed to such fire, from what would have happen'd to them in the focus of a burning lens, or speculum; and these too very different, according to the peculiar natures of such heterogeneous parts mixed with the fire. But then these different effects do not arise from fire, as fire; but from fire, as combined with other corpuscles agitated by it; though the whole, by mistake, be promiscuously attributed to some diversity in fire. In the mean while, the effect of fire on bodies is found very different, according to the different fuels it is sustain'd by; whence it becomes either stronger or weaker, or even mixes part of the fuel agitated, and often, as it were, united to it, with the bodies exposed to it's action.

14. In respect of this, therefore, that fire is judged the purest, which is *In alcohol.* produced and maintained by burning alcohol; as adulterating bodies the least with any mixture of it's fuel.

15. The next is that produced by distill'd oils, frequently rectified and *Distill'd oils.* cleansed, especially from their fixed alkaline salt, and thus render'd exceedingly thin, simple, subtile and limpid, like alcohol itself. To this class belong naphtha and petroleum, wherein the like property obtains.

16. After these, good charcoal yields the purest fire. — Then the purer *Wood-coal.* natural woods themselves. — Then turf, or bituminous clods, which are of two kinds; the first pared from the surface of heathy ground, the other dug out of a moist, black, fat mud or soil, in a parallelepiped form; which being dried by the sun afford a noble, wholesome, settled fire, much esteem'd and praised by Mr. Boyle.

17. The coal of such turf being duly prepared, by kindling it till tho' *Turf.* roughly ignited, so as to emit no sensible smoke, and then extinguishing it; if kept dry, will afford a fuel very easy to be kindled, and fit for various purposes, in regard it neither produces smoke nor stench; but when once lighted, spontaneously maintains its fire a long time, and is the most equable of all hitherto observed.

18. To these more compound fuels belong also pit-coal; which consists *Pit-coal, &c.* of a fossil oil much like naphtha or petroleum, and a vitrifiable matter (i).

19. And lastly, the dried dungs of certain animals.

20. That vast diversity, therefore, of physical effects, which seems so often to arise from the operation of fire, ought to be wholly attributed to the diversity of fuel; as might be shewn by many, and particularly by the following experiments. If wood or turf be burnt in an open fire in the air, the vapour they yield is by no means mortal, but painful to the eyes, and affecting the lungs so as to cause a cough; but the same being, either of

(i) " The smoke pit-coal being very offen-
" sive, and other inconveniencies attending its
" use; a way has been found to char, and
" reduce it into coherent masses of a proper
" size. 'Tis true it is sold almost as dear as
" charcoal; yet those who consume large quan-
" tities, find it near twice as cheap, because it
" lasts much longer, and gives a heat far more
" intense. It would therefore be a very useful

" thing in chemistry, to be able to char coals
" without the use of those pots, to which their
" present price is owing. In *Holland* they have
" likewise a way of charring peat, a kind of
" turf, which might serve for fuel in chemi-
" cal operations; tho' the manner of charring
" be not yet known in several countries, where
" perhaps peat might be found.

them, charr'd or prepared after the manner above specified, and thus lighted thoroughly, when very dry, yield a very thin scarcely perceivable fume, which if confined in a close place, presently kills all animals: and this with some extraordinary circumstances. For an animal being put in a large vessel, and then the air so far exhausted, as that the animal might still live some time in it; and lastly, air being driven through coal still smoaking, and convey'd by a funnel into this kind of vacuum, the animal did not die; whereas the same air being driven through coals perfectly kindled, instantly suffocated the creature. The air also sometimes communicates an extraordinary power to fire; as appears from that experiment related by the celebrated historian of *America*, *Acosta*; viz. that in the rich silver-mines of *Peru*, the native metal, while in its ore, will not melt with the utmost fire raised by the largest bellows; but that it readily melts, if the same fire be excited by an artificial blast of wind, raised by a swift fall of cold water, conveyed forcibly by proper instruments into the fire. These, and many other instances, shew how necessary it is to be very circumspect in examining the action of fire on bodies; since the minutest circumstance often alters the whole effect.

21. It remains now to consider some things further in this history of fire, which may be of great use in chemistry.

Fire no universal solvent.

22. First, then, we must not give into the vulgarly received opinion, that fire is an universal solvent of all bodies. 'Tis certain it dissolves a great number of bodies; but that it dissolves all, we positively deny. In reality, according to its different degree, it acts differently on the same object. Thus, if very small, and gradually raised, it will, in a long course of time, turn quicksilver in a glass phial into a sort of fixed powder, scarce miscible with any other liquor; whereas, if the same utmost degree of fire had been applied at first, as at last; the quicksilver would all have evaporated. And again, if the same highest degree of fire be suddenly applied to this powder, thus fixed by a slow one, gently raised, the whole becomes volatile again: so that one degree destroys what another had done.

Nor a pure one.

23. Secondly, neither is fire so pure a solvent, as only to extract from bodies what before existed in them; since it mixes some things with them at the same time that it extracts others; of which we have many indications. Thus while antimony is calcining by the solar fire, it occasions it to emit a copious fume; yet at the same time introduces such a quantity of other matter, that the calx is increased both in bulk and weight. And if lead, by the like operation, be reduced to minium, it all the while yields a plentiful poisonous fume; and yet the calx becomes considerably heavier than the metal originally was. The like augmentation of weight is found in coral, when calcined by a vehement fire long continued. So mercury, if well purified by means of metals, and then digested a long time in a glass phial by fire, turns at length into a fixed powder, and a small quantity of good metal, weighing together more than the mercury first employed.

Nor always powerful.

24. Fire, from some bodies, produces nothing new; but lets them pass unchanged, and untouched as it were: as we find in gold, silver, osseo-

osteocolla, glass, *selenitis*, talc, and virgin-sand; which are not separated into elements, or any other bodies by fire alone, however applied (k).

25. There are many bodies from which fire, in what manner soever applied, will not, of itself, separate any different parts; though it be known that different parts concurred to the composition of such bodies; and tho' by other means we can actually resolve them into such component parts. Various instances hereof have been long ago alledged by learned authors: we shall only mention a few. If gold, silver, and copper be melted, and thus mix'd together, they will afford a mass; out of which the fire will scarce ever extract those three ingredients. But if we put this mixture, with twenty times the quantity of lead, in a refiner's furnace, the copper will very soon be accurately separated; leaving the gold and silver pure behind. And if these two be again exposed, in what manner soever, to the fire, they will still remain mixed; and this so intimately, that each particle of the mass shall contain the same proportion of gold and silver, as is found in the whole mass. But if spirit of nitre be poured on the same, all the silver will be dissolved, and the gold remain at the bottom of the vessel, in form of a black powder. The silver thus separated from the gold, and conceal'd in the spirit of nitre, is very difficultly separable therefrom without loss: for with fire it will dry into a mass, called *lapis infernalis*, wherein the acid part of the nitre still obstinately adheres to the silver, and melts with it, like a metal, yielding no smoke. But if a quantity of thin pieces of copper be added to the solution, the whole body of the silver, gradually separating from the spirit of nitre, will gently adhere to the copper; and the vessel being shaken, fall to the bottom thereof; and being washed with fair water, become perfectly pure: so that what the fire could not do, is here done by other means. I need not add, that sulphurs adhere so strongly to the ores in metals, that, when exposed to the fire, they either melt, or evaporate with them into the air. How vainly, and with what immense loss, have the refiners of metals endeavoured to expel the sulphurous parts by fire, so as to obtain only the metalline parts pure at the bottom of the test? But when they came to mix fix'd alcalies, or iron, which in the fire attract sulphur, or absorbent powders made of these or the like matters, with the ore; the sulphur absorbing such addition, and uniting the sulphurous scoriae with itself, left the metalline part pure behind. Thus antimoney, when pure, appears homogeneous; but if exposed in any manner to the fire, either evaporates wholly, or if the fire be slow, remains fixed therein: but upon mixing it with tartar and nitre, or with iron and nitre, and then deflagrating the mixture, an heterogeneous sulphurous part presently separates from the rest, leaving a metalline, homogeneous, ponderous mass behind. The same antimony is dissolvable in its metalline part by *aqua regia*, whilst its sulphur remains untouch'd by the acid thereof. Sal-ammoniac, which is a composition of various matters, evaporates wholly in a strong fire, and in a lesser remains unchang'd; but upon adding to it a fix'd alkaline salt, it presently separates into a fixed sea-salt and a volatile animal one. So corrosive-sublimate of mercury, exposed to a long continued fire, suffers no

The separable otherwise.

B b b

division

(k) See *Helmont* in various places; and *Boyle Abr.* Vol. III. p. 266, & seq.

division of its component parts; but upon mixing with it a quantity of iron or alcalies, becomes freed of its acids. Chemistry abounds with similar instances.

*Fire does not
separate bodies
into their ele-
mentary parts.*

26. It is further remarkable, that those parts which fire, however carefully applied, procures from compound bodies, are not simple, but still variously mixed together. If we examine the simple waters drawn from bodies by fire, they evidently appear, both by their smell, the thickness they spontaneously acquire, and their mucilage, to be still much compounded; since none of these ever obtain in truly simple water. If we consider spirits, they will be found so compounded of water, and a salt inherent therein, that there is no separating them perfectly by any art, without applying both fixed salts and fire. For oils, the generality of chemists allow them as true, simple, sulphureous elements; but the more knowing few shew them to be compounded of a great variety of parts; viz. that inflammable principle, of which we have already treated so fully, a large proportion of water, a quantity of salt intimately mixed, and some earth. And what extreme care does it require, before the earth obtained from bodies by fire can be had absolutely pure; fixed salts still adhering to it, even till it vitrifies?

*But even
compounds
them.*

27. It appears, by the result of numerous experiments, that fire compounds bodies, as well as divides them; being found to unite different matters so closely together, that the whole resulting therefrom appears extremely simple; and will even bear the fire afterwards, without being changed. Thus, pure sand and fixed alcali being intimately mixed by grinding, calcining, and melting them together, with a vehement fire, produce glass; which is a body so simple both in its parts, and the whole, that we scarce know another more simple one, or harder to be resolved into its ingredients; which can only be effected by melting it with a great proportion of fixed alcali, sufficient to give it a saline nature, and then digesting it in an acid; upon which the sand precipitates to the bottom, in form of a fine powder. The same is shewn by sapo's; also by the distillations of *aqua regia*; and by the *electra* of metals. In fine, all nature makes use of fire, as the chief instrument of producing compounds. What compound do we find, either in the animal, vegetable, or fossil kingdom, but owes its origin to a gentle, digesting, arranging, compounding fire? In reality, a slow sedate action of fire in motion, appears the principal cause of all the closest combinations we meet with; so that it may well be doubted, whether fire contributes more to the composition, or the dissolution of bodies.

*Both mixes
and separates.*

28. It may be observed, that the same fire, as applied in different quantities, first compounds bodies, and, when raised to a higher pitch, decompounds them again. This the chemists have found, to their no small loss; when after employing many years to fix mercury by a slow fire, gently raised through several degrees, they have at length brought it into a red powder, which remains long fixed in the fire; yet when the same fire is raised to its utmost pitch by force of bellows, this likewise evaporates into the air; whereby, at the same time they were disappointed in their expectation they learnt

learn't this secret; viz. that one degree of fire will separate, what another had compounded.

29. One and the same fire, applied to the same body with different circumstances, will have quite different effects; and especially as the air happens to be variously admitted, during the operation. Dr. Hook took a coal, put it in an iron box, and closed the same very accurately with a lid screw'd down: then applying the whole a long time over a strong fire, the coal, upon taking it out again, was not found burnt (l). From whence he inferr'd, that air is a menstruum, which being agitated by fire, could dissolve all sulphurous bodies; which, fire without air could not do (m). The same has been observed by *Helmont* in distillations with his fixed coal; and by *Papin* (n). I myself have burnt the fine dust of *guaiacum*, with a vehement fire long continued; yet have found the black *sæces* remaining with the oil in them, which no force of fire could drive out of the retort. Yet no sooner was this carbonaceous powder laid in a shallow basin, and a small spark of fire applied to it, than the black oil all exhaled with an aromatic cedar-like fume; leaving nothing behind but white tasteless ashes. Thus camphire, when kindled in air, even though it were swimming on water, will burn quite away; but if put in a subliming glass-vessel over the fire, it will melt, rise to the top, and concrete into new camphire, altogether the same as before. And the like will happen, though the operation be repeated a number of times. Thus sulphur, in close vessels, will sublime a hundred times; yet still remain sulphur: but if during the operation, a crack happen in the vessel, and the melted sulphur becomes by this contiguous to the air; it im-

B b b 2

mediately

(l) See his life prefixed to his posthumous works, p. xxi.

(m) The truth is, in some cases, the presence of air is necessary for the production of light, or preservation of fire: as appears from the burning of those bodies which go out when the air is taken away: thus a lighted candle being put in a receiver, and the air exhausted, the candle is immediately extinguished: nor will the ordinary attrition of a flint and steel produce any spark of light in *vacuo*. On the contrary, on some occasions the absence of the air is necessary to light. Lastly, in other cases, the light which was before seen in the air, becomes augmented upon taking away the air; as we see in the lucid lines drawn by phosphorus*.

"For the sake of those who think the attrition of contiguous air necessary to produce a manifest heat, we placed some hard black pitch in a basin, at a convenient distance under water, and cast the sun's rays on it with a burning glass, in such manner that, notwithstanding the refraction they suffered in passing thro' the water, the focus falling on the pitch, would pro-

duce sometimes bubbles, sometimes smoke, and quickly communicate a degree of heat, able to melt it, if not also to make it boil †. We took a pistol, and having firmly tied it to a stick almost as long as the cavity of the receiver, we primed it with dry gun-powder; then cocking it, we fasten'd the trigger to one end of a string, the other being fasten'd to the key in the cover of our receiver: this done, we convey'd the whole apparatus into the vessel, which being closed up, and emptied after the usual manner, we turn'd the key in the cover, and thereby shortning the string, pulled the trigger, and observ'd, that the force of the spring of the lock, was not sensibly abated by the absence of the air; for the cock falling with its usual violence, struck as many, and as conspicuous sparks of fire, as, for aught we could perceive, it did in the open air. Upon often repeating this experiment, we could not perceive, but that the sparks of fire moved upwards, downwards, and sideways, as when out of the receiver †."

(n) See his *Recueil des Machines*, p. 25, 26.

* *s' Gravesand.*

† *Boyle Phys. Mech. Exper. on Air.*

† *Boyle Mech. Orig. of Heat, &c.*

mediately catches fire, and resolves into a blue flame and acid fume. So amber, if kindled in the open air, burns almost wholly away, maintaining a fire and flame: but if the same be distill'd in a retort, with a fire at first very gentle, but gradually raised to the highest pitch: it will first yield a water, spirit, volatile acid salt, and an oil of different kinds; and at length, by the highest degree of fire, the whole substance will rise through the neck of the retort, as I have often experienced. It follows therefore, that fire, either without air, or pent up with it, and restrain'd from motion, has very different effects, from what it is found to have under other circumstances.

And differently according to its degrees.

30. The same fire, as applied in different degrees to the same object, has very different effects, as we find by experiments. For if the white of a new-laid egg be put in a clean open vessel, and kept in a degree of heat, denoted by 92 degrees on *Fahrenheit's* thermometer, it will in a short time be turn'd into a thinner, sanious, fetid, putrid liquor, incapable of being again coagulated by the heat of boiling water; and at length becomes a volatile fetid alkali: but if the same white of egg be kept in the 200th degree of heat on the same thermometer, it quickly turns to a white, solid, scissile, insipid mass, and yields plenty of aqueous, inodorous, insipid fume; leaving at bottom a hard, brittle, pellucid, insipid, inodorous matter, which will remain immutable for many years. Again, the same white being put in a clean glass retort in 400 degrees of heat, yields phlegm, spirits, fetid oils, volatile, alkaline, oleous, and fetid salt, with a black coal which swells exceedingly by the fire.—There would be no end, were I to rehearse all that might be said of the nature and power of fire. It may now suffice to give a short recapitulation of the doctrine laid down in the foregoing articles; as that fire, diversified according to all the preceding conditions, may produce most of the effects observed in nature, we mean as a concurrent cause; viz. it may change concretes, both in their figures and cohesions, but so as that the diversity of concretes will hereby produce different things; it being never observed, that fire can produce the same things from different ones, but only certain definite things from certain bodies, and these also different according to the order, degree, and manner of application of the fire.

Of the Direction and Regulation of Fire in Chemistry.

1. **I**T remains now to speak of that knowledge of fire, considered as present and acting in any given place, which is requisite in a chemist, to enable him to raise, direct, maintain, and apply the degree of fire necessary to produce the desired change in a given body. This part of knowledge indeed is delivered by the antient chemists, but has been brought almost to perfection in our days, since the way has been found of applying *M. Fahrenheit's* excellent thermometer to this purpose. The antients teach, that the power of fire may commodiously be divided into four different degrees, which they hold sufficient to the practice of their art, but say little very distinctly on that head; nor have the generality of moderns added any thing considerable to their doctrine. Our endeavour will be in what follows to reduce the rules of art to more natural principles.

2. The first degree of fire then is that which in nature performs the office of vegetation in plants, and whereby chemistry imitates, or does the like. This commences from the highest degree of cold, which in *Fahrenheit's* thermometer is denoted by one, and ends at 80 degrees; since, in this whole interval, we find certain plants give indications of life and growth. Thus in the severest winter's cold we find the bitter mosses growing on the barks of trees; and what is more, they only grow at such times; the fir, juniper, oriental larch, cedar, pine, larch, yew, life-tree, and other ever-greens, maintain their verdure during the most pinching frost: the like holds of corallines, earth-mosses, black hellebore, hepatica, the *Leucosian* narcissus, the winter aconite, helleboraster, and others, which will flourish, blossom, generate, conceive, and bring forth under the severest cold, which is unable to check their conjugal heat. In fine, were we to rise from the lowest to the highest pitch of this degree of heat, and then rehearse all the species of known plants, we should find some which arrive at their utmost strength in every point or degree of the heat above-mentioned.

The degrees of fire, viz. The first.

3. Hence it appears probable, that a chemist, by duly conducting this degree of heat in an artificial stove, might imitate the heat which nature makes use of in the production of plants; proceeding by gentle degrees, so as to cherish, not destroy them. To raise this degree, let a furnace be made and on this set a vessel full of water, to which a thermometer being applied, may by its rising and falling indicate the degree of heat required; then placing glass-vessels in the water thus temper'd, put the bodies therein, which are to undergo the action of the fire: 'tis very probable this degree of fire would be fittest for impregnating of oils with any excellent, precious, vegetable spirit without wasting. Thus, to communicate the fragrant scent of roses to a given oil, the best method should seem to be to take pure, inodorous, insipid oil of olives, and put it in a tall clean chemical fire, and digest it in a heat of 56 degrees with roses, gather'd just as they open in the morning; by such means the warmth will unite the spirit of the rose with the viscosity of the oil, in the most intimate manner, and exhibit an highly odorous balsam. The application of a similar degree of heat would impregnate alcohol with the finest spirit of saffron; a lesser degree scarce sufficing to extract this spirit from its body, whilst a greater will dissipate the more volatile part of the same spirit. Few conceive the justness of this method; and yet 'tis certain several incomparable medicines are thus prepared, merely by a cautious management of the fire; which are utterly lost if the fire be raised beyond the proper degree.

And its uses.

4. The second degree of fire may commodiously be taken from the heat which ordinarily obtains in an healthy man, and which may be supposed to commence at the 40th degree of the thermometer, and end about the 94th. Within this compass animals may live and subsist; that is, if their juices be of any degree of heat within these bounds. The vital juices of some insects have indeed a very small degree of heat; and I have often wonder'd how the embryo's in the ova of caterpillars, which fix their fecundified eggs by a viscus to the slender branches of trees, should have subsisted unhurt during the whole hard winter of the years 1709 and 1729, when

The second degree.

when every body would have imagined this whole race of worms must have been destroy'd by so severe a frost; yet as the warmth of the spring approach'd, we found them creep out of their *ovula*; and consequently they must have bore the whole severity of the season without harm. So fishes, both of the river and sea kind, which have gills instead of lungs, live in a watery medium, which is only 34 degrees hot; and consequently their bodies are reduced to the same temperature; yet they can bear any heat from hence to the 60th degree, and somewhat further: but fishes that are furnished with lungs, as also all breathing animals, conceive a greater heat of their juices, which, when healthy, are found about 92 degrees hot; for which reason we limit this second degree of fire between 33 and 94 degrees: within which compass the vital functions of all animals, the fermentations of vegetables, and the putrefactions of animals and vegetables, as well as all generations, gestations, incubations, births, nutritions, &c. of animals are performed. This degree is used by the best chemists for making elixirs, volatile alkaline salts, both simple and oily, also tinctures, and the digesting of the philosophical mercury for the first preparation of the stone.

And it's uses.

The third degree, and it's uses.

5. The third degree of fire is that which extends from 94 degrees of the thermometer to 212; at which last, water usually boils. In the whole compass of this degree the water and native spirits are separated from all vegetables and animals, and the remainder drying, becomes durable, and almost immutable; the essential oils of plants thus become volatile; but the salts and oils obtainable from the recent juices of animals, scarce rise within this degree, but rather dry into a thick, hard, brittle, insipid, inodorous matter, which remains unchang'd for many years; by which appears the falshood of that usual opinion, that volatile, alkaline, and oily salts are generated and found in the healthy bodies of men, with this degree of heat. All distill'd oils are prepared, and also all distillations of medicated waters from vegetables are made in this; and the sanguineous and serous humours of animals coagulate by boiling water into scissile masses; all their solid parts are destroyed and turned into a thick tenacious liquid; consequently all animals are quickly destroyed therein.

The fourth degree.

6. The fourth degree may be taken from 212 to 600 degrees on the thermometer; within which latitude the distillation of all oils, saline lixiviums, quicksilver, and oil of vitriol, is performable. Within this also lead and tin will melt and mix together; oils, salts, and saps both of animals and vegetables, become volatile and acrimonious, tending more or less to an alkaline nature; their solid parts dry up, and burn into a black coal. In fine, all these matters are utterly destroyed, have their nature chang'd, and lose their proper powers in this degree of heat: and fossile sulphur and sal ammoniac are sublimed by the same.

The fifth.

7. The fifth degree is that wherein the other metals melt, and which commences from 600 degrees of the thermometer, and ends where iron is held in a state of fusion. In this degree most bodies are destroyed; but glass, gold, silver, copper, and iron, remain long unchang'd; all other fixed bodies, grow red-hot in this degree: the fixed salts of vegetables and fossils melt
are

are deprived of most of their oils, and raised further and further towards an alkaline acrimony, and thus with sand or flint turn to glass; in this lime-stones calcine, and all other bodies vitrify, or become volatile, and dissipate in the air.

8. The sixth and last degree of fire is that made either by a burning lens ^{The sixth.} or a speculum, which scarce any substance is able to withstand, and gold itself becomes considerably alter'd thereby: concerning this degree of fire consult *Homborg's*, *Hartsoeker's*, and *Villette's* experiments; as also what we have already delivered in the course of this history. Its usual and almost universal effect on all bodies is their vitrification; whence we lay it down, that the ultimate effort of any fire hitherto discovered is to vitrify all fixed bodies. This the antient sages of *Asia* seem to have been apprized of; as they relate in their predictions, that the whole world should at length perish by fire, and be turned into transparent glass. Thus much at least we have sufficiently made out concerning the degrees of fire; human understanding being unable to fix its ultimate limits. It will now be necessary to shew how a fire may be raised, and maintained in any given degree; upon which the whole art of the chemist immediately depends.

9. In respect of this we observe, that it is much more difficult to pre-serve a great degree of cold for a long time, than to maintain a great degree of heat for an equal continuance; as sufficiently appears from the works of glass-men, forgers, and founders of metals, &c. — Now the way to guide and moderate the fire, is first by making choice of such among the fewels above rehearsed, as is fit for raising the requisite degree of fire. Alcohol affords a very feeble but equable flame, which may easily be guided by the lighting a greater or less number of wicks: for the requisite degree of fire being settled, there remains nothing but to light a lamp furnished with a sufficient number of wicks to raise the thermometer to the degree desired. After alcohol follow other light, porous, and spongy fewels, as hay, straw, rushes, dried leaves, hair, feathers, saw-dust, barks, chaff, bran, &c. and after these, oils, tallow, wax, camphire, pitch, rosin, sulphur, and other combustibles prepared from these; then the thick hard heavy woods, not over dry, and the coals made from thence; and lastly, red-hot metals and pit-coal.

10. A different degree of fire may also be raised, from the lowest to the highest, by the quantity of the fewel applied; since if a great heap of this be thrown on and kindled together, the fire produced thereby will be proportionably greater and stronger; it being a rule here, as every where, that *vis unita fortior*.

11. The degree of heat produced, also differs, with regard to the object to be changed, according to the distance at which the fire is applied to it, by reason the heat necessarily diminishes as that distance is greater. Some philosophers having imagin'd, that this diversity might be reduced to a simple law; as holding that the powers of corporeal qualities decrease in a reciprocal ratio of the squares of the distance, from the centre of the body which exerts such quality; and accordingly, that at a double distance from the fire its power will be four times less. But to admit this for a rule, we should

should first be certain whether the fire itself, when collected into less space does not acquire some new powers, which do not depend on the mere number of the fiery particles, but on some other power arising from their closer contact. If this be considered, we shall find it true, that the nearer the fire, the greater always the heat; but that the law of such increase or decrease is very different from the general one first laid down; since in making experiments with care, we find a sudden great diminution of the force of fire at a very small distance from the body that emits it, which diminution increases, the further we recede from the fire, tho' not in the same, but a less proportion. From whence it appears probable, that the particles of fire, besides that power which they have in acting on any other bodies, have some other power arising from a relative motion produced by their being very near each other. For as *Grimaldi* and *Sir Isaac Newton* have observed, that the particles of fire, when ready to strike against opaque reflected bodies, acquire new motions by the vicinity of such bodies; those particles may perhaps acquire something of the same kind by their vicinity to each other: but of this matter we have spoke more fully above.

By agitation
and compression.

12. Lastly, the degree of fire may be modified by shaking, stirring, and compressing its fuel, or the airy vault surrounding it: These make a great increase in the violence of fire, and the greater as they are stronger, provided the vault be not destroyed by them, as we have above explain'd: and since we have no more commodious and cogent way of producing this agitation and compression than by blowing, or driving a stream of air upon the fire, bellows hence become of extraordinary use to press the air closer against the surface of the fire, and hereby shake the fire compressed under it; as has been already shewn in speaking of this aerial vault around a kindled fire: where we likewise observed, that if the blasts of a great number of forcible bellows were directed from different parts of the circumference, around a fire to the same point in it, its power would be directed with still greater violence upon an object placed in such point, and consequently make a greater alteration therein: this artifice is accordingly used by refiners and assayers, when they require the highest degree of fire.

The figure of
the furnace.

13. To these may be added, a fifth method of ordering the degree of fire; viz. by means of the arched figure of the furnace, disposed to reflect the fire, and collect it into a given place of the focus (o).

14. To say no more; if the five above-mentioned helps be applied at the same time, we shall have the greatest possible degree of vulgar fire.

Conclusion of
the doctrine of
fire.

15. These are the chief matters which I had to deliver concerning the natural history of fire, as it is concerned in chemistry. They have cost me indeed much labour; to what purpose I must leave to others: but thus much I think I have fully shewn may safely be inferred hence, that a fire of the same definite fuel, degree, and manner of application will always have the same effect, on the same object, whether it be to separate or combine; and that unless those conditions be first accurately assign'd, nothing certain can be concluded concerning the action of fire on bodies; consequently, that in describing chemical operations, the greatest care must always

(o) See hereafter the article of FURNACES.

always be taken to be very precise on those heads, which accordingly we have been very solicitous to do thro' the course of this chapter. By such means might the art of chemistry be reduced into a science equally certain and regular with others. The degree of fire, then, is always to be expressed, as also the succession of degrees, the fuel it is supported by, with the weight of the atmosphere, its warmth, motion, wind, or blast; and lastly, the object itself: this will prevent a person being led into error, who shall undertake to imitate the same.

16. To the whole, we may add a few circumstances relating to the nature of fire; as that fire does not want air, nitre, fuel, sulphur, or any other body. The true naphtha catches fire the easiest of all known bodies, at a considerable distance from the flame; and the like holds of the purest petroleum (p). Bodies smear'd with this liquor of naphtha, and then kindled and thrown under water, continue still to burn (q). Naphtha will kindle by the flame of a candle, even placed in a lanthorn, and thus excluded from any contact with it (r). Gun-powder being enclosed in a machine, which water could not penetrate, and a clock enclosed together with it, which should at a certain time, by striking a flint against a steel, set fire to the powder, and the whole being let down to the bottom of the sea, the powder was accordingly kindled there, a great rumbling noise heard, and a thick smoke raised from the same, but no flame (s): An experiment very considerable, and which may afford matter of much speculation. Sibbald relates something still more singular concerning the lake *Strath-Erith*, whose water never freezes, even in the severest cold, before the month of February; but often afterwards, even with a single night's frost, will be cover'd with a strong ice (t). This seems to argue, that as the heat increases in one place, it increases the cold proportionably in another; which is further confirmed from a remarkable observation of a little brook which never freezes, even in the coldest season (u). And the same is still further confirmed, from what is related by the Abbot *Boissot*, and *du Hamel* (x); viz. that about five leagues distant from *Vesuntion* in France, there is a cave three hundred paces deep, which, in a hot season, yields more ice in one day's time, than the carts and mules can carry off in eight days; being often found to rise to four feet thickness; whilst in the winter-time it shows only a thick vapour, with a rivulet running in the middle; which rivulet is always frozen in summer. When the vapour appears in this cave, it is looked on as a certain prognostic of rain speedily to ensue. So we find in green-houses, and stoves, where plants are kept in winter, that the more the heat is increased in some places, the more severe is the cold in others, where the fire cannot reach. So in the smelting-houses for iron and smiths forges, the more violently the fire burns, the greater cold is found in the adjacent places.

17.

(p) *Journ. des Sav.* 1675. p. 53.

(q) *Journ. des Sav.* 1683. p. 104.

(r) *Philos. Transact.* 100. p. 188.

(s) *Sinclair, de Aer. Gravitat.* p. 301.

(t) *Scot. Illustrat.*

(u) *Philos. Transact.* No. 56 p. 1139. *Abridged.* V. II. p. 335.

(x) See *Journ. Sav.* 1686. p. 336. & *Hist. Acad. Scient.* p. 257.

The Theory of CHEMISTRY.

17. Thus much for the nature of that wonderful cause, which the Creator has lodged in the universe, with a power of exciting such motions in bodies, as are necessary for effecting those great alterations, every where found throughout the world. I here leave the matter, after having examin'd it with my utmost endeavours, to be further pursued by others. There are infinite things still remaining to be discovered in it, which may afford room for sagacity and beneficence to find out and impart to mankind, in order to enable them more fully to understand and adore the power and wisdom of the Creator, from a clearer view of his works.



Of AIR.

1. **O**UR next step is to treat of air, whose action and concurrence are used in most of the operations, both of nature and art; consequently its properties and powers are to be thoroughly understood, in order to a knowledge of the manner wherein physical alterations are made. But as this is more compound than fire itself, its nature accordingly becomes more difficult to investigate; so that to get an insight into its hidden properties, we must set out as if we were utterly ignorant of it; and proceed with the same caution as we have already done in the discovery of fire. — By air, then, we mean a fluid scarcely perceivable by our senses, and which only discovers itself by the resistance it makes to the velocity of moving bodies; or by its own vehement motion against other bodies, called wind (*y*). This we find by experiments is every where incumbent over the surface

Air, how to be enquired into.

(*y*) Mr. Boyle conjectures the atmospherical air to consist of three different kinds of corpuscles: the first, those numberless particles, which, in the form of vapours, or dry exhalations, ascend from the earth, water, minerals, vegetables, animals, &c. in a word, whatever substances are elevated by the celestial, or subterranean heat, and thence diffused into the atmosphere. The second may be yet more subtle, and consist of those exceedingly minute atoms, the magnetical effluvia of the earth, with other innumerable particles sent from the bodies of the celestial luminaries, and causing, by their impulse, the idea of light in us. The third sort is its characteristic and essential property, we mean permanently elastic parts*.

The same author gives us several experiments and methods for the production of air; taking the word *production* for the obtaining a sensible quantity of that fluid from bodies wherein it did not before appear either at all, or in so great plenty; though perhaps some of his experiments may argue a new and real production of air in the stricter sense of the word.

“ Among the several ways of producing air, the fittest for practice seem to be fermentation, corrosion, and the dissolution of bodies, by the boiling of water and other liquors; by the mutual action of bodies upon one another, especially saline ones; and lastly, by analyzing and resolving certain substances†.

‘ I have found that various, solid, and mineral bodies, unsuspected of elasticity, being plunged in corrosive unelastical menstrua, will, upon a proper comminution of their parts, afford, in the conflict, a considerable quantity of permanently elastic air†.’

Sir *I. Newton* shews that gunpowder generates air; *i. e.* by explosion it goes off in a flaming smoke, or red-hot exhalation, consisting chiefly of the spirit of nitre, rarified by the accension of the sulphur and charcoal, and driven off much after the manner of water out of an eolipile; the volatile sulphur, at the same time, and the fixed body of nitre, joining with it, and increasing the effect||.

Some of the later authors divide air into *transient* or *apparent*, and *permanent* or *real*: for that all which appears to be air, does not continue such, is evident hence, that if an eolipile of water be sufficiently heated, and suffered to expel the particles of air by its aqueous vapour; this will afterwards be forcibly driven out in a large quantity, like the blast of a pair of bellows, and occasion a sharp, whistling noise against the edge of a knife conveniently held thereto: yet such a vapour, tho’ whilst the motion last it resembles air, soon loses that resemblance; especially in the cold; and returns, by condensation, to its original water.

‘ Various hypotheses may be framed relating to the structure of the particles of air. They might be resembled to the springs of watches, coiled up and endeavouring

C c 2

* Boyle Abr. Vol. III. p. 16, 17.

† Optics, p. 317.

† Ibid.

† Boyle.

surface of our earth: in this mankind live; this they continually breathe, and are necessarily every moment inspiring and expiring to support life; so that all assistances of art, exclusive of the help of air, would be of no use to its preservation (z.)

2.

“ vouring to restore themselves; to flocks of wool, which being compressed, have an elastic force; to slender wires of different substances, consistencies, lengths, and thickness, in greater curls, or less, near to or remote from each other, &c. yet all continuing springs, expansible and compressible. Lastly, they may also be compared to the thin shavings of different kinds of wood, various in their lengths, breadth, and thickness.”

(z) In an express treatise on the *wholesomeness and unwholesomeness of the air*, Mr. Boyle makes appear, that it depends principally on the impregnation the air receives from subterranean effluvia, a cause generally overlook'd by physicians; of which he distinguishes diverse kinds, *viz.* ordinary, which are almost constantly sending up; extraordinary, which rise but at certain times. These, again, if they come at stated seasons, he calls *periodical*, if uncertainly, *fortuitous* or irregular.

In the general, tho' the wholesomeness of the air in some places may be chiefly due to the wholesome expirations of subterranean bodies; yet is the air depraved in far more places than it is improved, by being impregnated with mineral expirations. Indeed, among the minerals known to us, there are many more noxious than wholesome; and the power of the former to do mischief is more efficacious than of the latter to do good; as we may guess by the small benefit men receive in point of health, by the effluvia of any mineral, or other known fossil, in comparison of the great and sudden damage that is often done by the expirations of orpiment, sandrac, and white arsenic.

Among the various sorts of particles where-with the atmosphere is replete, some, he shews, may be so small and solid, or so conveniently shaped, as to enter many of the numerous orifices of the minute glandules of the skin, or at other pores thereof. Thus, tho' neither paper, nor a bladder, be pervious to the elastic parts of the air; yet may either of them be easily penetrated by other corpuscles of the atmosphere: and that excellent author has prepared a dry body, which being inclosed in either, would, without wetting or discolouring, or any way sensibly altering them, pass in a trice thro' the pores thereof, in such plenty as

to exert a manifest operation on bodies placed at some distance therefrom.

This is confirmed from the sudden check almost every summer given to the plague at *Grand Cairo*: for, since morbid causes operate more effectually than curative ones; it seems more than probable, that exhalations ascending from under ground, may produce pestilential fevers, and the plague itself; since the corpuscles which impregnate the *Egyptian* air upon the swelling of the *Nile*, put a speedy stop not only to the contagion, but to the malignity of the plague, assisted even by the summer's heat, which there is excessive.

'Tis very probable, that most of the diseases, which even physicians call *new*, are caused either principally or secondarily, by subterranean steams.

Indeed, there may be noxious minerals in a country, without being often able to produce pestilences: they may lie in beds so deep, that even a small earthquake shall not reach so far downwards as to affect them; tho' a more violent shock may. And hence we may account for the plague's raging in some parts of *Africa*, once in thirty, or once in a hundred years; since there may be periodical paroxysms, or grand and vehement commotions in subterranean parts, tho' not yet observed in them. A late judicious *French* historian records, that a very pernicious disease, of the nature of a choleric, reign'd in *France* every tenth year, for seventy years together.

Mexeray relates, 'That the great plague, which happen'd in *France* in the year 1346, and which was so contagious that scarce a village, or even an house, escape uninfected, began, two years before, in the kingdom, of *Cathay*, by a vapour most horribly fetid, and breaking out of the earth, like a kind of subterranean fire; which consumed and devoured above two hundred leagues of that country, even to the very trees and stones; and infected the air in a wonderful manner.' He adds, 'that from *Cathay* it passed into *Asia* and *Greece*, thence into *Africa*, and afterwards into *Europe*, which it ransacked throughout.'

And not only plagues, but most new, contagious, and epidemical diseases, Mr. Boyle takes to arise from subterraneous causes. He instances

* Boyle Abr. Vol. III. p. 17. 21, &c.

† Hist. de France.

2. If we trace the order of nature, it will be found, that this air is an *An almost universal agent.* universal, necessary, and most efficacious instrument, which nature is perpetually applying in almost all her works; for in this all the species of bodies are placed, in this they perform their motions, and exert the several actions, which arise either from the proper and peculiar nature and powers of each, or from the mutual relative powers between them. Nay, it will hereafter be shewn from experiments, that there is scarce any fluid, with whose particles air is not mixed; or any solid, from whence air may not be extracted by art; so that it would be very difficult to assign any known operation of nature, which is performed without air, excepting, perhaps, those of magnetism, gravity, and the particular attraction and repulsion between the particles of bodies, which seem capable of being performed without air; but for all the rest, this instrument is indispensably necessary: and for the operations of chemistry they are all performed in air, without one exception that I know of; unless alchemists imagine, that the matter of the philosopher's stone, duly prepared, and carefully inclosed in the philosophical egg, is to be destitute of all crude air, and succeeds better *in vacuo* than in the air itself: it being a constant principle among them all, that nothing is a greater impediment to the maturation of this wonderful work than crude air; but this probably is rather to be understood of the other ingredients mixed with air than of the pure element itself. 'Tis certain that fire, which moves all things, can scarce be collected, preserved, directed, heighten'd, or abated without air; and consequently if air be necessary to fire, it is also necessary to all the works performed by it; since without air, fire ceases to operate, nor can be applied at all: where, by fire I mean that kindled and preserved by a proper fuel, which is that used both by art and nature in most of their works; and for which, we have already shewn, by a great variety of arguments, that fire is absolutely required (a),

Animates fire.

stances a great cold, which, in one day or two, invaded multitudes in the same city, with violent and fatal symptoms; when yet, he could see no room to judge, that the bare coldness of the air could so suddenly produce a disease so epidemical and hurtful; and it appear'd more probable, that the cause came from under ground, because it began with a very troublesome fog.

Peculiar kinds of venomous exhalations, 'tis probable, may sometimes be emitted, especially after earthquakes; and thus occasion mortal diseases in animals of one kind, and not of another; and in this or that place, and not elsewhere. *Fernelius* gives us an account of a plague or murrain in 1514, which invaded none but cats. *Dionysius Halicarnassensis* mentions a plague which attacked none but maids: and that which raged in the time of *Gentilis* killed scarce any women, and very few but lusty men. *Boterus* mentions another great plague which assaulted none but the younger sort:

3. and we have instances of the same kind of a later standing. *Cardan* speaks of a plague at *Basil*, with which the *Switzers*, and not the *Italians*, *Germans*, or *French*, were infected: and *Job. Utenbovius* takes notice of a cruel plague at *Copenhagen*; which, tho' it raged among the *Danes*, spared the *Germans*, *Dutch*, and *English*, who went with all freedom, and without the least danger, to the houses of the infected*.

(a) We are extremely apt to be too precipitate in our conclusions; after having learnt a few of the properties of a body, we think we have got all, and impose it on ourselves to account for all the phenomena and effects thereof, how various soever, from what we do know. Hence innumerable crude, constrained solutions. No body appears to have been more on his guard, in this respect, than *Mr. Boyle*: he saw abundance of effects from air, which did not appear to have any dependance on the known mechanical properties thereof; and on this

* *Boyle Abr.* Vol. III. p. 521.

*Asuates ani-
mals, vegeta-
bles, and fossils.*

*The action of
air in the
bowels of the
earth.*

3. If we examine the most universal species or classes of bodies, it is evident they every where require air, in order to live, grow, thrive, and act; for if life in these be only a motion of their several humours through their proper vessels, a converting of other matters by some inherent power into their own nature, or at least the apposition of such matters to their own mass, from whence arises an increase of their magnitude; it does not appear that any one of these can ever be effected without the continual action and assistance of the air.

4. The chemists will perhaps wonder to hear me alledge air as necessary in the œconomy of fossils, whose great simplicity of matter seems only to require the action of fire to enable them to act, or undergo every thing that belongs to this species of things; but the skilful enquirers into nature have long ago discovered that fossils, even in the deepest mines, generate, multiply, and are driven upwards; all which is performed by some peculiar power of the subterraneous fire: but then it is also evident, that such subterraneous fire, as perpetual as it is, is only retained, collected, and applied in such places by means of air. It may be worth while to set this matter in a clearer light, in regard it has not hitherto been well stated. Air, which is fluid, heavy, elastic, dense, in proportion to the weight wherewith it is compressed, acts more strongly by the same fire, in proportion to the density it has acquired; expands in proportion as it is freed from the compression of weights; and rarifies in proportion to the fire which acts on it: This air, we say, insinuates into all bodies, penetrates into the very bowels of the earth, and more especially exerts all its powers towards the centre

this view composed that excellent piece of *Suspensions about some hidden qualities of the air.* 'The difficulty, says he, we find in keeping flame and fire alive, tho' but for a little time, without air, renders it suspicious, that there may be dispersed through the atmosphere, some odd substances, either of a solar, astral, or subterraneous nature; on account whereof, the air is so necessary to the subsistence of flame. And this necessity I have found to be more considerable, and less dependant upon the manifest attributes of the air, than is usually observed; for by trials purposely made, it has appeared that a small flame of a lamp, tho' fed perhaps with a subtile thin oil, would in a large receiver, expire for want of air, in a far less time than one would believe. And it will not much lessen the difficulty to alledge, that either the gross fuliginous smoke in a large vessel, stifled the flame; or that the pressure of the air is requisite to impel up the aliment into the wicks; for to obviate these objections, it may be observed, that the experiment holds of spirit of wine which, in the open air, will burn quite a-
* *Boyle Abr. Vol. III. p. 76, & seq.*

way, without any sensible smoke; and this without any wick at all.'

Again, — 'It seems surprizing what should be in the air, which enabling it to keep flame alive, does yet, by being consumed or removed, so suddenly render the air unfit to preserve flame. It should seem, by the sudden wasting or spoiling of this fine substance, whatever it be, that the bulk of it is but very small, in proportion to the air it impregnates with its virtue; for after the extinction of the flame, the air in the receiver was not visibly alter'd, and, for aught I could perceive, by several ways of judging, the air retained either all, or the greatest part of its elasticity; which I take to be its most genuine and distinguishing property. This undestroyed springiness of the air, with the necessity of fresh air to the life of hot animals, suggests a great suspicion of some vital substance, if I may so call it, diffused through the air, whether it be a volatile nitre, or rather some anonymous substance, sidereal or subterranean; tho' not improbably of kin to that which seems so necessary to the maintenance of other flames.'

centre thereof: Hence then it will always act more violently in the earth, in proportion as it is deeper and denser, and more agitated by the fire, more plentifully collected by this attrition of the air; and thus becomes the physical cause of the strong compression, attrition, purification, and collection of homogeneous matters; whence it is, that the fossils here produced are endued with the like nature. Nothing of this, therefore, could be effected without air; and hence we have a probable reason why those bodies are only generated there; but of this we shall have occasion to speak hereafter; all we here intend to shew is, that the presence and active power of air are necessary in all the operations of nature.

5. Nor need we expatiate on the power of air upon vegetables and plants; it being known, by the most accurate modern experiments, that no eggs of animals, or seeds of vegetables, however mature and prolific, will, if kept without air, ever breed or produce their embryo's, even though they be cherished with the proper brooding heat. Thus even the smallest plants, for instance mosses and weeds floating on water, immediately die in a place where there is no air, or even when the air stagnates, and is at rest: and the same holds true of all animals, even the minutest insect: so great is the dominion of the air over all things. *Its necessity to the production of animals.*

6. An exact knowledge of the air, therefore, comprehending its active properties, is absolutely necessary, both to a chemist, a physician, and a philosopher, in order to understand the productions both of art and nature; one of the chief causes and agents wherein is some innate property of air, no where else existing. *Its knowledge necessary.*

7. In the mean while, there is not perhaps any body more difficult to be perfectly understood, in regard it does not of itself, and by its own nature, affect the organs of our senses, by reason doubtless of its great subtilty, which escapes the grossness of our nerves; so that even the most perfect microscopes discover nothing in it. What renders it still more difficult to understand, is, that it contains within it various kinds of other bodies, so that we scarcely find any fluid in nature, composed of such a variety of different ingredients; and it will be shewn in the course of this chapter, that there is scarce any species of bodies, some parts of which are not found floating in the air; gold itself, though one of the least volatile, not excepted. *The difficulty of the enquiry.*

8. Hence, the more necessary it will be to examine all its properties distinctly and separately, taking care not to admit any confusion therein; and after each of them has been thus severally considered, it only remains to collect all the observations into one aggregate, and we shall have as just a knowledge of the nature of air, as the subject will admit. *How to be less'n'd.*

9. The first property which appears in the consideration of air is its fluidity. This indeed is so essential to air, that we do not find any instance wherein it was ever taken from it. *That air is fluid.*

10. 'Tis obvious, that in the keenest frost, when every thing else congeals, air still remains fluid; so in a cold, 40 degrees greater than nature ever made, the air has been found fluid, though excessively constringed; and if air be compressed into the smallest space, by the greatest power or

or weights, it still remains equally fluid, and when the compression is abated, returns to its former fluidity. Among a great number of experiments, wherein I have mixed a great variety of liquors, and by this means have procured a multitude of different coagulums; I have never met with a single instance, which shew'd that common air might be coagulated into a solid mass. 'Tis true, I have sometimes observed, upon viewing the air at noon in a cold clear day, a number of little corpuscles floating in it, which shined by the sun's rays, and even sparkled by the different reflection of these rays, as the little surfaces of the corpuscles happen'd to change their situation; but upon further examination, I have found that these were only little glebes or masses, formed out of particles of water dispersed in the air, collected together, and as it were frozen into the form of a subtile floating hoarfrost. So that if fire be able to cohere and consolidate with other bodies, of which we have spoken in the preceding chapter, air would be much more tenacious of its natural fluidity than fire itself. But to me it rather seems probable, that there are in nature two fluids, whose particles never unite or cohere, either with themselves, or with any other matters, so as to form an homogeneous mass; and these are air and fire: though it must be remember'd, that this same air coheres with all kinds of known bodies, and thus conspires as an element to the composition of concretes, as sufficiently appears by the great quantity of air, which arises from almost all bodies, when resolved into their elements. This the late philosophers call, though perhaps with little propriety, factitious air: upon examination it appears, that this air is contained in all known fluids, and penetrates, together with these, into all the recesses of solids, so as upon the coalition thereof, it is stopped and detained in their pores, as in so many minute bubbles, and at last, upon the dissipation of the fluid, wherewith it was at first introduced, is left alone: from whence it clearly appears, that the air here had not cohered or united with the body, but only been detain'd or imprisoned therein; and accordingly, no sooner does it find a passage, than it immediately flies out, and resumes its former nature. This may be further shewn from the instance of common water, when turning to ice, wherein a great quantity of air is lodged, though invisible; for as soon as the water begins to cohere, and its parts become closer applied to each other, wanting the power of fire, which is necessary to separate the particles from each other, and hinder them from joining in their mutual natural embraces, the particles of air, intercepted between those of the water, are unable to cohere, but are extruded out of the pores of the water, united with other aerial particles, and thus separating from the water, gather into bubbles, and constitute a fluid air, as before. This shews, that the air did not cohere or coagulate, that it only remain'd intercepted, not alter'd; and the like being found in all other cases, we may lay down fluidity as the first property of air.

*Owing to its
tenuity of
parts.*

11. This fluidity of air seems, in the first place, owing to the tenuity of its parts, which are so exceedingly fine, as to be incapable of being render'd visible by any microscope; and yet they must be much larger than those of fire, in regard they cannot penetrate metals, glass, stones, the closer woods, nor even good paper itself; and hence air may also be excluded

cluded from many bodies, and cannot even pass thro' the invisible pores of some, that would admit of alcohol, wine, oil, water, brine, lixiviums, and alkaline or acid spirits; as appears from the air-pump experiments: for here the ring of leather, laid upon the brass plate of the air-pump, to support the glass receiver, being pressed upon by the edges of the glass; and the air being extracted from its cavity, the weight of the atmosphere presses the edges close to the leather; upon which, the external air will not enter thro' the pores of the leather, under the edges into the receiver, but be intirely kept out: whereas if any of the above-mentioned liquors be externally poured upon the leather ring, they will soon be sucked up by it, insinuate themselves under the edges, and get into the receiver: which plainly shews, that even thick and viscid liquors may easily enter, where air will not; and the same might be shewn by many other experiments.

12. These smallest particles of air, are so easily separated from each other, that, in order to separate them, even a less force is required than our senses can perceive; and this separation is equally easy in every direction. That air is so easily divisible, any one may find, by observing the motion of a small smooth body thro' that fluid at rest: thus, a needle may be moved in any direction thro' the air that surrounds it; and the like holds in all other similar cases: this property of air, I shall hereafter call its lubricity.

13. Upon carefully examining into this property, it should seem as if there was a certain attraction between these particles of air, whereby they easily run into mutual contact, tho' of a very slight and separable kind; thus, when a single particle of air lies concealed in any fluid, we cannot perceive the least signs of it; but if another joins it, we presently perceive a little air-bubble made of the two; which bubble resists its separation by a certain tenacity: if another such bubble or two be added to the former, 'tis manifest they make a larger, that retains its peculiar magnitude and spherical figure. This, it may be suspected, is owing to the compressure of the surrounding fluid: and by allowing it to be so, it will follow, that there is a stronger attraction between the particles of air and air, than between those of air and the particles of the compressing fluid; and doubtless the attraction between these particles is exceeding small. Some might suspect that repulsion takes place here, according to what Sir Isaac Newton has shewn (b). This may be possible, and we shall treat of it below: in the mean

The lubricity of the parts of air.

Their mutual attraction.

(b) The instance of air and vapours, which seem to discover some such repelling power, that illustrious author brings as an argument of the same power being found in other bodies.—'The particles emitted or shaken off from bodies by heat or fermentation, says he, so soon as they are beyond the reach of the attraction of the body, recede from it, and also from one another, with great strength, and keep at a distance; so as sometimes to take above a million of times more space than they did before, in the form of

' a dense body: which vast contraction and expansion seems unintelligible, by feigning the particles of air to be springy and ramous, or rolled up like hoops, or, by any other means than a repulsive power.

' The particles of fluids, which do not cohere too strongly, and are of such smallness, as renders them most susceptible of those agitations, which keep liquors in a fluor, are most easily separated, and rarified into vapour, and in the language of the chemists, are *volatile*, rarifying with an easy heat, and condensing

D d d

mean time, we lay it down as certain, that these particles have a power of uniting into a spherical figure, and thus of long defending themselves against the surrounding pressure.

Their miscibility with others.

14. For, upon a closer examination of this attractive principle, we shall find that these particles of air, when single, presently insinuate into, and mix themselves with any liquor that is destitute of air, adhere tenaciously to it, and lodge quietly in the interstices thereof; after the manner of salts dissolved in water: on the other hand, we shall see hereafter, that a large bubble of air, consisting of many aerial particles united, being placed upon the surface of a liquor purged of air, resolves into its particles, which being thus disjoined, slip into the interstices left in the liquid, without ever collecting into bubbles again, unless a fresh cause be applied.

Whence its imperceptibility.

15. And hence we may understand the above-mentioned imperceptibility of air, with respect to our senses: for we should have had no notion of air, the subject we are treating, without observing the motion of large bodies thro' it, and particularly of such as have much surface, and are moved broadways: for thus we are presently made sensible, that air by its strong resistance, is a corporeal substance: and as this resistance increases in a duplicate ratio of the velocity of the moving body; 'tis manifest it may be prodigiously augmented. For example, let any one attempt to move a thin copper-plate of a hundred square feet, perpendicularly, with its flat side forwards, in a still air, at the rate of 22 feet in a second, and he will be sensible of an almost incredible resistance, which may easily be computed on M. Mariotte's principles. This is to be understood of the entire air as a compound, wherein not only light and small bodies, but also large and heavy ones may float; as we see by the flight of birds, and bodies carried away by the winds.

Its absolute gravity.

16. The next thing to be considered of air is its entire weight, or the weight of the atmosphere. *Torricelli* attempted to discover it statically, in the year 1643; *Otto Guericke* confirm'd it by experiments, in the year 1655; it was afterwards illustrated by M. *Pascal*, carried further by Mr. *Boyle*, and finished by M. *Mariotte*, in a set of elegant experiments; so that at present nothing seems better established in all physics (c).

17. But

• condescending with cold: but, those which are
• grosser, and so less susceptible of agitation,
• cohere by a stronger attraction, and are not
• separated without stronger heat, or perhaps
• not without fermentation, and these last are
• the bodies, which chemists call *fixed*; which,
• being rarified by fermentation, become true
• permanent air; those particles receding from
• one another with the greatest force, and be-
• ing most difficultly brought together, which,
• upon contact, cohere most strongly.

• And because the particles of permanent
• air are grosser, and arise from denser sub-
• stances than those of vapours, thence it is

• that true air is more ponderous than vapour,
• and that a moist atmosphere is lighter than
• a dry one. *Opticks*, p. 371, 372.

(c) We have sensible demonstrations of the thing from experiment; thus the hand applied so as to cover the orifice of a receiver, upon working the air-pump, and thus withdrawing the subjacent air, soon feels the load; so exhausting the air from a thin, square glass receiver, the pressure of the incumbent air easily bursts it: again, two hollow segments of a sphere exactly fitting each other, being exhausted of their air, and thus exposed to the pressure of the external air, will sustain a force of

17. But the comparative weight of air still remained difficult to determine; *its relative gravity.* it appearing upon trial, that no two equal bulks thereof, taken at the same time at different heights, were equiponderant, but that the lower always weighed more than the upper; and this was found true, beginning at the surface of the earth, and proceeding to the tops of the highest mountains: and even at the same place at different times, an equal bulk of air does not retain the same weight, but suffers a great variety.

18. Again the atmosphere in our climate, where-ever it has hitherto been tried, is subject to great and almost perpetual changes with respect to its weight, which never remains the same long together. *The variable-ness of its weight.* This difference is chiefly found on the change of meteors in the air, which frequently happens: thus, the atmosphere has a different weight upon the coming on of rain, showers, mist, hail, snow, lightning, thunder, coruscation, alterations of the wind, storms, whirlwind, droughts, and the changes of the aspects of the planets: even the different seasons of the year occasion surprising changes therein; so that the constant, and successive mutability, depending upon so many renewable causes, renders the atmosphere ever variable in its weight: whence also proceed numerous effects about the surface of the earth, depending chiefly upon the variable weight of the air, which is continually changing (*d*). We learn from careful observation, made and continued for the space of 86 years; that the greatest and least difference, here in *Europe*, in this weight of the atmosphere, is equal to that of 30 inches and $\frac{1}{2}$, and 27 and $\frac{1}{2}$ of mercury in the barometer; so that the difference is about $\frac{1}{16}$ part of the greatest weight.

19. This frequent change in the weight of the air depends upon many *Reducible to rule.* different causes; and as these causes are certain, they may be discovered by careful and accurate observations, so as to assign the reason of this fluctuation and uncertainty. *Nicolas Cruquius* has shewn us the way of bringing this matter to a certainty, in his meteorological tables, formed with great industry and exactness; where we see at one view, all the causes that contribute to increase the weight of the atmosphere in every degree. It were to be wished, that a proper inducement might encourage others to follow the example of so useful an inquirer into natural philosophy.

20. It was also at length discovered, that the common weight of the air *The weight of air compared with water.* about our earth, in a mean weight of the atmosphere, and in a mean temperature of the year, is to that of water nearly as 1 to 850; tho' this is to be understood according to the conditions above laid down, otherwise nothing certain can be determined about it.

D d d 2

21. The

of 140 pounds, supposing their diameter three inches, before they separate: to say no more, the rising of mercury in the barometer to the height of 28 inches, and of water in pumps, &c. to that of 32 feet, are incontestable proofs of the weight of the air. See the writers on hydrostatics, *Boyle, Wolfius, s' Gravesande, &c.*

(*d*) Thus the difference of the air in point of gravity may come to have a very considera-

ble influence on the healths of men. 'When the air, says Mr. Boyle, grows of a sudden much lighter than usual, the spirituous and aerial particles, plentifully lodged in the blood, will naturally swell that liquor, and so distend the greater vessels, and alter the manner of the circulation thro' the capillary veins and arteries; whence several changes may happen in the body.' *Hist. of Air.*

*The effects of
the weight of
the atmo-
sphere.*

21. The air, by its weight, continually presses upon the surface of our earth, with a force equal to that which sustains a perpendicular column of quicksilver at the same height, it then stands at in the barometer; the base of which column is an horizontal plane, cutting a pyramid, whose vertex is in the center of the earth, and whose sides touch the horizontal limits of the body pressed upon by the incumbent atmosphere: so that this power may every where be exactly calculated, from knowing the height of the mercury in the barometer, and the quantity of surface pressed upon. And hence it follows, that bodies, situated in the earth, sustain a greater pressure from the incumbent atmosphere, the nearer they are to the center of the earth: for, it appears from hydrostatics, that fluids press upon their bases in proportion to their altitudes; so that, if air be considered as an homogeneous incompressible fluid, we may easily compute in what proportion it presses upon bodies in any part of a perpendicular, tending from the surface to the center of the earth (*e*): but as the elastic property of the air greatly alters the case, we shall treat of its effect below. Hence all bodies, contiguous to the air, are never long pressed upon by the same external weight; the pressure varying almost every moment; tho' the difference in the same place never exceeds $\frac{1}{10}$ of the whole. While the air thus presses bodies with a different force, it is also repelled by such as are elastic, or have a natural power of expanding themselves, or recovering their own bulk: whence all such bodies, contiguous to the air, have a constant oscillation in their parts, corresponding reciprocally to the increase or decrease of the weight of the air; and tho' this difference be small, as never exceeding $\frac{1}{10}$, yet it is always something, and nearly perpetual. It was observed in the history of fire, that the parts of bodies had another tremulous vibration, depending upon the vicissitude of heat and cold; and this, with the present, may produce considerable and constant effects: so that we must allow these two causes, *viz.* fire and air, productive of a constant internal motion in all the parts of elastic bodies. It may here be added, that on bodies absolutely soft, if any such there are, or perfectly unelastic, as water for example, which cannot be compressed by external weight, the weight of the atmosphere cannot act by any increase, or diminution of its weight, and consequently such bodies will hence have no tremulous motion in their parts: but

(*e*) * The atmosphere in its free state may be considered, as if it had once been water, covering the earth to the height of 31 feet; but afterwards exceedingly rarified, expanded, and converted into what we call air; which, tho' in fact it possesses a larger space, has not a greater weight than water of the height of 31 feet: now it is easy to compute what quantity of water would every way surround the earth to that height, which gives the whole weight of the air; for, since a cubic foot of water weighs seventy two pounds, a prism thereof (to use that for the sector of a sphere) whose base is a foot

square, and height 31 feet, will weigh 2232 pounds; and since the surface of the earth contains 3711.420000.000000 square feet, the product of these two sums, which is 8.283889.440000.000000 pounds, gives the quantity of water, and consequently the quantity of air required. *Pascal, Traité de l'Equilibre des Liqueurs.*

Hence, when a column of quicksilver, 30 inches high, is sustained in the barometer, as it frequently happens; a column of air, that presses upon an inch square near the surface of the earth, must weigh above 15 avoirdupois pounds. *Id. ibid.*

but then, as fire acts more upon such bodies than upon any others, it is plain, that the force of fire is much more general in this respect than that of air.

22. It may be proper, with regard to chemistry, that we next consider the effects of the external air, as it is at once both a fluid and heavy body: for as such, we have already seen, it externally presses upon the surfaces of all bodies; and hence it will insinuate it self into the surfaces of all those bodies, whose pores are large enough to receive its subtile particles, or whose texture is slight enough to admit them: whence we may infer, that the pores of bodies, which to us appear empty, may be full of common air; which air will produce its proper effects in those pores: and upon this, numerous natural effects frequently depend. 'Tis a curious observation in hydrostatics, that air, as a gravitating fluid, presses bodies equally every way; as laterally, horizontally, vertically, upwards, downwards, and obliquely. This is demonstrated in that science; but as chemists are seldom acquainted therewith, it may be proper to prove a truth of such moment in chemistry, by a familiar example. Take three glass vessels, the one of a cylindrical figure A, the other conical B, the third bellied C, with a cylindrical neck; 'tis plain from geometry, that all the kinds of simple vessels may be referred to these three: let these be filled to the brim with fair water, and covered with a single piece of paper, so as to touch the surface of the water, and by pressing it down with the hand, prevent the external air insinuating between the paper and the water; if the glasses be now inverted, whilst the paper remains pressed close with the palm of the hand, and the hand be afterwards gently withdrawn, the water will still remain in the glasses; and the same holds true, tho' the glasses be held horizontal, or in any other position: whence we see that air, as a heavy fluid, presses equally upwards, laterally, downwards, &c. Archimedes, observing this property of every gravitating fluid, has raised many noble demonstrations upon it; and indeed numerous consequences might hence be deduced, which we leave mechanics to explain, whilst we make use of them only as chemists. Hence it appears, that the air presses upon all the points of a surface exposed to it, and enters into all the pores it can come at, however they are situated, constantly pressing against them with an equal weight, tho' always more as the body is situated lower therein. And by these its properties, air compresses bodies on all sides, fills up their cavities, and forms a strong compressing surface about them; and hence it happens, that both the external and internal air, which is always supposed a moveable fluid, and by its gravity applies it self to the surfaces of fluids, impinges against, shakes, moves and agitates their superficial parts; whence it wonderfully mixes these different fluids together, excites and applies their forces reciprocally, and thus constantly produces numerous effects: yet it does not change the figures of the bodies it touches, except so far only as they have pores void of air; but if they are capable of yielding to the air's pressure, they will thus be condensed and lessened in their bulk; otherwise the air with all its weight cannot break even the weakest and most brittle body, that, being replete with air, rests in the atmosphere: the external pressure in this case being exactly

The effect of the air as a fluid and heavy body.

Plate 6. Fig.

exactly equal to the internal. On the other hand we know, that the air is always in considerable rapid motion; as clearly appears from hence, that in a still place, suppose a close darkened chamber, illumined only by one small hole in the window-shutter, where, if a person at rest views the enlightened cone of air sideways, as it extends along the room, he will perceive a surprising motion of the dusty atoms therein, perpetually rolling and tossing about with great rapidity: whence it may be fairly concluded, that the same thing happens, in a higher degree, in the external open air; so as to excite a still greater agitation, motion, and attrition in the bodies it hits against; since the motion is here perpetual, and the power of gravity in the air equal to that of a column of water thirty-three foot high. Hence it is easy to conceive, how great a degree of motion and attrition the atmosphere exerts upon the surfaces of all bodies, especially when a large bulk of it is put into a rapid motion, either by fire or violent winds: thus supposing a body of 2080 pound weight to press, by its gravity, upon an area of a foot square, and this body to be moved by a violent storm, at the rate of twenty-two feet in a second, it must needs exert a prodigious force against the body it moves upon: and hence numerous and great physical changes are every moment performed by these causes; which chemists overlooking, fly to other abstruse and fictitious ones for explaining the same effects. But here we must remember, that the smallest particles of air cohere together in such a manner, as not to be easily separable so far as readily to enter the smallest pores of bodies, but must first form themselves into bubbles of some size, before they can insinuate; this appears by the following experiment. Take a thermometer-glass four foot long, the diameter of its tube being only $\frac{1}{4}$ of an inch; perfectly fill it with water; and if now it be inverted, not a drop of the water will run out, but the whole remain suspended, as if the open end was carefully closed: so in the common barometer, filled with quicksilver, no air is forced up into the vacuum at the top of the tube, tho' the atmosphere presses with all its weight upon the surface of the quicksilver below; for here the air cannot divide itself into such small particles, as to enter the interstices of the quicksilver, but remains excluded. The same experiment holds, tho' made with water, or even alcohol itself; whence it is plain, that air cannot be easily divided into its smallest particles, otherwise they would pass thro' the pores of these fluids, wherein however the particles of air may be concealed, as we shall manifest hereafter: at present we shall attempt to shew the size of these bubbles, under which air ascends thro' water in tubes. Take a thermometer-glass with a long stem, whose diameter is $\frac{1}{4}$ of an inch, fill it with water and invert it, the air will now ascend up thro' the water in large bubbles, without separating it self into small ones; whilst some, of a considerable magnitude, stick up and down in the neck of the glass: here therefore, there is either an attracting quality in the air, or a repelling force in the liquors with respect to the air, driving its particles into contact. The following experiment may give more light to the affair: into a glass vessel of alcohol invert a thermometer-glass full of water, the orifice of which glass air would not enter, when held inverted therein; the alcohol will here ascend in curling veins thro' the water to the top of the ball, whilst the

water

water descends into the glass deserted by the alcohol, till the two liquors entirely change their places: whence I conclude, that the parts of alcohol and water do, by their single force of gravity and fluidity, easily pass thro' the interstices of each other, whilst air does it with difficulty. The same is proved evidently by using oil instead of alcohol, and proceeding as above; and the like effect is found upon inverting a thermometer-glass of a saturated lixivium into water, alcohol, or oil. This property of air therefore, as compared with other fluids, we recommend to the farther consideration of chemists; to shew why the particles of air, collected into a bubble, are much more difficult to separate than the particles of any other known fluid; whence the smallest particles of air do not readily mix with other fluids, but rather unite with each other within them, so as to manifest themselves therein by bubbles, or froth, which is a collection of bubbles; and whence, when single particles of air separately lodge themselves in the deserted pores of other fluids, they are hard to be got out; thus it is extremely difficult perfectly to separate air concealed in quicksilver; which when once done, what strange phenomena may ensue, we learn from M. *Huygens*, who found that quicksilver, well purged of air, stood at the height of above fifty inches in the barometer: but of this property of the air I shall more expressly treat hereafter.

Hitherto I have endeavoured to explain those properties of air, which it has in common with other bodies, together with the effects thence arising in chemical operations; as also transiently its miscibility with other fluids: I next proceed to consider its peculiar properties.

23. The first of these is its elasticity, by which is meant that particular power wherewith all known air, confined in a certain space, so that it cannot escape, contracts its dimensions upon pressure, in proportion to the weight applied; but so as always to restore it self by its own natural expansive power, in proportion as the weight is lessened; where, if no other cause intervenes, it constantly returns to the same space it possessed before, when the compressing force is removed; and stretches farther, if the power be diminished (*f*). *The elasticity of air.*

(*f*) The elasticity of air is as its density; for this last is inversely as the space taken up by the air, and therefore as the force compressing the air, which is equal to that by which the air endeavours to expand itself, but this force is its elasticity. *s' Gravesand's Elem. Phys.*

' The air is loaded by the weight of the whole atmosphere, pressing every way according to the nature of a fluid; the force it exerts, does no way depend upon the elasticity; because, whether you suppose elasticity or not, that force which arises from the weight of the atmosphere, and is equal to it, can no way be changed: but, as the air is elastic, it is reduced to such a space by the weight of the atmosphere, as that the elasticity, which re-acts against the compressing weight, is equal to that weight. But the elasticity increases and diminishes

' as the distance of the particles diminishes or increases; and it is no matter, whether the air be retained in a certain space by the weight of the atmosphere, or any other way; for in either case, it will endeavour to expand itself with the same force, and press every way. Therefore if the air near the earth be included in any vessel, without altering its density, the pressure of the included air will be equal to the weight of the whole atmosphere. Thus we find mercury sustained to the same height by the elastic force of air included in a glass vessel no way communicating with the external air, as by the weight of the whole atmosphere.' *Id. ibid.*

' The effects of the elasticity of the air are like those of its gravity; and included air acts by elasticity, just as air not included by its weight.' *Id. ibid.*

Peculiar to it. 24. This kind of elasticity I do not remember to have been observed in any other fluid; 'tis never found in alcohol, oil, water, spirits, or lixiviums, tho' these all easily expand with heat, and contract with cold, but they are not compressible by weight: this therefore may be a peculiar property of the air alone, and should be carefully explain'd, as we shall endeavour to do from the discoveries of Mr. Boyle and M. Mariotte.

The laws of its elasticity. 25. These gentlemen found, by experiments, the first law of this elasticity, and consequently its density, to be always proportionable to the compressing weight. Suppose a strong cylindrical vessel, the area of whose basis is a foot square, and its height sixty-four inches, to be filled with air; this air will sustain upon its upper surface the pressure of the atmosphere, which we may suppose to be 2112 pound *Troy*; 'tis plain, the air in the tube will then be as common air: if now its upper surface be pressed upon by the incumbent weight of quicksilver, rising to the height of twenty-nine inches, it will then sustain a pressure twice as great as that of the atmosphere alone; and so in proportion the air will be compressed according to the following table, viz.

If 2112 fills the tube		
4224	-	$\frac{1}{2}$
8448	-	$\frac{1}{3}$
16896	-	$\frac{1}{4}$
33792	-	$\frac{1}{5}$
67584	-	$\frac{1}{6}$
135168	-	$\frac{1}{7}$
260336	-	$\frac{1}{8}$ &c.

Hence it appears difficult to find a way of compressing air into a $\frac{1}{8}$ part of the space it naturally possesses, when such a prodigious weight, and so strong a tube, of so considerable a height as 203 inches, are required for the purpose; and in this case, the weight of air would be to that of water, as 11 to 13; and upon doubling the weight of the mercury 11 times, the air would be reduced to a $\frac{1}{1000}$ of its natural bulk, and thus become much more dense, and ponderous than common water; but how much soever it is condensed, it will always retain some bulk, as appears by the table.

How far carried. 26. It will be shewn hereafter, that perhaps at least $\frac{1}{1000}$ part of common air consists of aqueous, spirituous, oily, saline liquids, and other corpuscles floating in it; which being brought together by this compression, will at length form an incompressible substance: whence it appears probable to me, that common air can never be condensed to $\frac{1}{1000}$ part of its bulk, without forming masses nearly solid; tho' these indeed, with respect to the elastic part of the air, may be always farther compressible, but never in proportion to the compressing weights; otherwise the bodies, mixed in among common air, must have the same degree of elasticity therewith; which is contrary to experiment. But as these incompressible parts in common air seldom make up $\frac{1}{1000}$ part of its bulk, 'tis no wonder that in the experiments, made to determine this law, this proportion should always be found;

a plain reason whereof will also appear below, when we come to consider Mr. Townley's experiments.

27. 'Tis easy by means of a compressing weight to reduce the common air to $\frac{1}{2}$ its bulk; and it has been accurately observed, that twice the weight gives it this degree of condensation; for, here the millesimal proportion of the incompressible particles is so small, as to be insensible in this primary condensation, so that here the rule corresponds to sight. *Plain in the first instance.*

28. But it is plainly more difficult to determine this law, in proportion as the air is more and more compressed: we see in hydrostaticks, that fluids press upon the bottom and sides of the containing vessels, in proportion to their perpendicular altitudes; whence very strong tubes would be necessary to carry on this experiment, so as to compress the air into a $\frac{1}{100}$ part of its natural space. It also appears by the observations of the academy *del Cimento*, that metallic vessels, filled with ponderous liquors, yield and grow larger; much more would vessels of glass do so: yet this is the matter here required for the purpose, in order to observe and mark the height of the compressing quicksilver, in proportion to that of the air compressed; since an exact knowledge, and just comparison of these heights, are here absolutely requisite. Besides, great caution must needs be required, the tube must be very high, not dilatable, of a perfectly even bore, and perfectly transparent; at the same time the air to be compressed, should, during the whole examination, remain constantly of the same equable heat; the least increase whereof will dilate the air more, as it is the more compressed by the incumbent weight. Physical experiments are made in the midst of a thousand concurring causes, any of which being neglected alters the case. *But less and less afterwards.*

29. To render this matter clearer, it may be worth while to relate after what manner philosophers discovered this law of the air's elasticity; whence we may the better judge what is reasonably to be thought of it, and of its expansion, which perhaps has been stretched too far. Mr. Boyle took a glass-tube *ABbc* bent, as expressed in the figure, open at *A*, hermetically sealed at *c*; it was nearly of an equal width at *bc*, and consisted of thick and very strong glass; the higher leg *bc* was 12 inches, accurately divided into lines, and the other leg *AB* was several feet in length; then by the pouring in of quicksilver, he condensed the air in *bc*, from 48 to 3, or from 16 to 1, and constantly found the space of the compressed air diminished proportionably, as the weight was increased (*g*). *The discovery of this law.* *Plate 7. Fig.*

30. As these have been the methods and limits of the observations, that shew air to be compressible in proportion to the weights applied; it appears, that this compressibility has not been observed farther than to $\frac{1}{100}$ part; nor do I remember any experiments published, that have carried it farther: Dr. Halley (*b*) indeed, and the academy *del Cimento* affirm, that air cannot be con-

(*g*) See Boyle *Abr.* Vol. II. p. 67. and *Maxims of the Nature of Air*, p. 151, 154.

(*b*) Dr. Halley asserts in the *Philosophical Transactions*, that from the experiments made at London, and by the Academy *del Cimento* at Florence, it may be safely concluded, that

no force is able to reduce air into 800 times less space than it naturally possesses on the surface of the earth. In answer to which, M. Amontons maintains that there is no fixing any bounds to its condensation at all; that greater weights will still bring it into less com-

condensed to less than $\frac{1}{32}$ (i), but they have not described the experiments, whereby they could compress it to such a degree as not to receive a farther compressure by the same means: however this matter be, 'tis certain that air, thus compressed, again dilates it self in proportion as the weight is lessened; and that this spontaneous dilatation constantly observes this law, upon the diminution of the weight, from 1 to 32, as Mr. Townley found by experiment, according to what Mr. Boyle relates in the place above cited; but from this limited experiment we must not draw too general a conclusion, and assert that the same law constantly holds, or that air is always compressible in proportion to the incumbent weight; which I believe is not determined. This much I my self have found to be true, viz. 1. That common air may be truly reduced, and consequently condensed, into a $\frac{1}{32}$ part of its natural space. 2. That it may expand it self equably into 32 times its natural dimensions. 3. That this contraction of air by compressure depends entirely upon the external weight applied. 4. That the air, freed from pressure, barely by removing the incumbent weight, does of its own nature, without any other cause, except the presence of fire, dilate it self, so as to recover the very dimensions it lost upon compressure. 5. That this expansive power, peculiar to air, remains in it, even after the strongest compression; as being always exactly proportional to the weight removed. 6. That 'tis always capable of sustaining pressure; for, even after its rarification to 32; by removing the weight, the air, thus rarified, may be recompressed by the same weight applied. 7. That this dilatation and compression of the air by weight exactly corresponds as to sense, with the increase, or diminution of the weight applied. As to that observation of the *Italians* and the *English*, that air cannot be compressed beyond $\frac{1}{32}$ part; since they have not taught us their method, I shall attempt to shew the great probability of the fact, when I come to treat of the corpuscles that float in common air. 8. That the spaces possessed by the same portion of air, are thus far in a reciprocal proportion of the compressing weight. 9. That this always holds in air, reduced to $\frac{1}{32}$ part of its space, as well as in that which is compressed by the atmosphere. 10. That in the whole extent, from 32 to 1, the proportion holds invariably the same, according to Mr. Townley's observations. 11. Whence it seems highly probable, that the same rule always holds in farther condensations; but so, that to make the same compression, a greater weight is required, as the air becomes more dense; till at length it remains no longer compressible. 12. That air, thus confined and compressed, does not pass thro' the pores of glass, nor even of quicksilver; for, it still remains in the tube, tho' so highly condensed by such an incumbent weight of mercury; nay, and if even heated in this state, so as to raise the mercury, still it neither penetrates that, nor the glass.

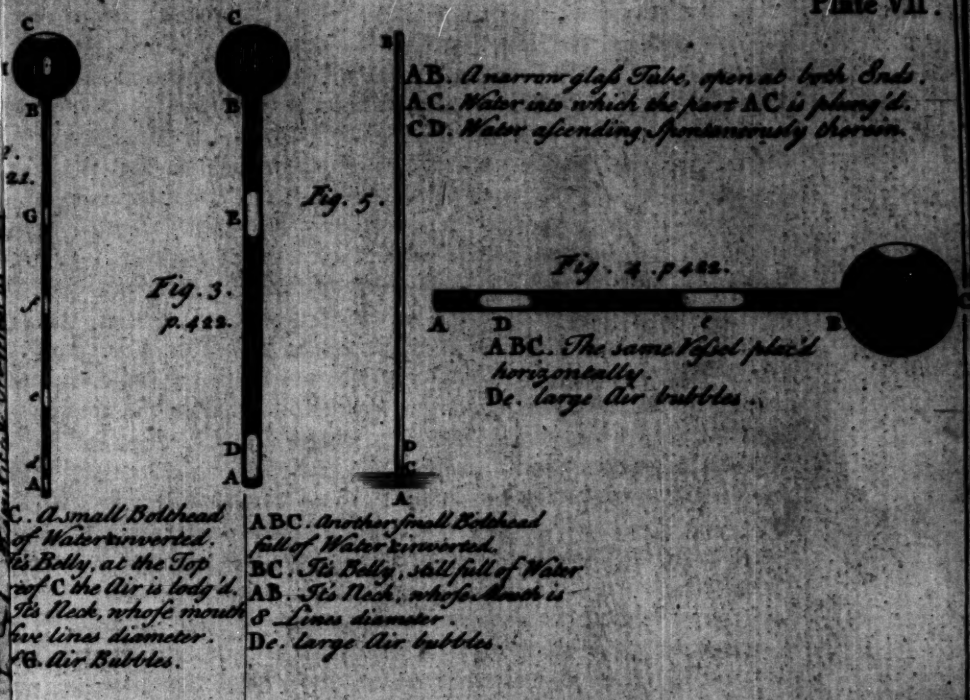
*Its elasticity
unalterable.*

31. Indestructibility is another law, that obtains in the air's elasticity; for, after all the experiments hitherto made upon it, the air has always remained elastic; so that neither long continued rest, nor violent compression,

compass; that it is only elastic in virtue of the fiery particles it contains, and that it is impossible absolutely to drive out all the

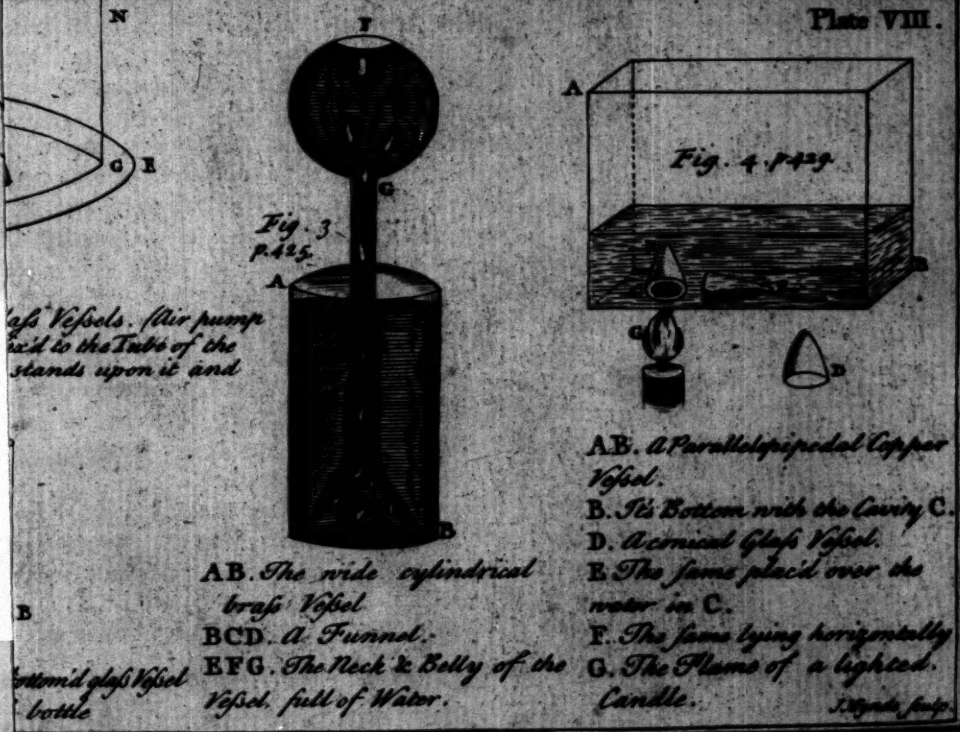
fire, and consequently to make a perfect condensation.

(i) See *Memoirs of the Royal Academy of Sciences*, An. 1703. p. 102.



Normal proportion to - mercury
 of the chemical elements

C. A small Botthead
 of Water inverted.
 Its Belly, at the Top
 of C the Air is lodg'd.
 Its Neck, whose mouth
 is five lines diameter.
 De. Air Bubbles.



glass Vessels. Air pump
 is'd to the Tube of the
 stands upon it and

bottom of glass Vessel
 bottle

J. H. H. H. H.

Fig. 1.
p. 393.



ABC. M. Boyle's
double Tube.
AB. The longest Leg.
bC. The shortest Leg.
A The Mouth.
C. The sealed End.

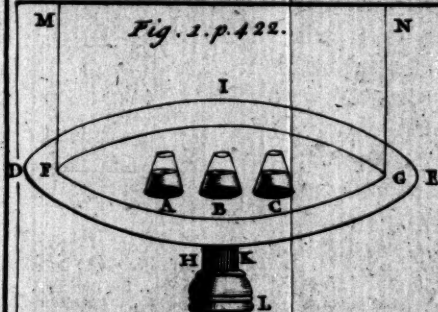
Fig. 1.
p. 421.



ABC. A small Botthead
full of Water inverted.
BC. It's Belly, at the Top
whereof C the Air is lodg'd.
AB. It's Neck, whose mouth
A is five lines diameter.
A defg. Air Bubbles.

Fig. 3.
p. 422

Fig. 1. p. 422.



ABC. Three conical Glass Vessels. (Air put
DHEI. The brass Plate fix'd to the Tube of the
FGMN. The Ball which stands upon it and
covers the Vessels ABC.

Fig. 2.
p. 423.



AB. The cylindrical flat bottom'd glass Vessel
CD. The spherical glass bottle

Plate VII.



Fig. 3.
p. 422.

Fig. 5.



AB. A narrow glass Tube, open at both Ends.
AC. Water into which the part AC is plung'd.
CD. Water ascending spontaneously therein.

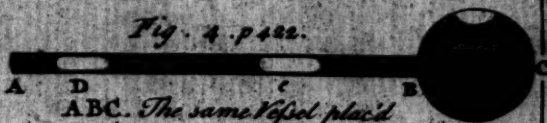


Fig. 4. p. 422.

ABC. The same Vessel plac'd horizontally.
De. large Air bubbles.

U. Bolt-head inverted.
at the Top
Air is lodg'd.
whose mouth
diameter.
bubbles.

ABC. Another small Bolt-head
full of Water inverted.
BC. It's Belly, still full of Water
AB. It's Neck, whose Mouth is
8 Lines diameter.
De. large Air bubbles.

N
I
G



Fig. 3.
p. 425.

ls. (Air pump
Tube of the
upon it and

AB. The wide cylindrical
glass Vessel
BCD. A Funnel.
EFG. The Neck & Belly of the
Vessel, full of Water.

Plate VIII.

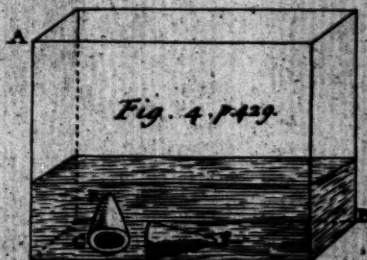


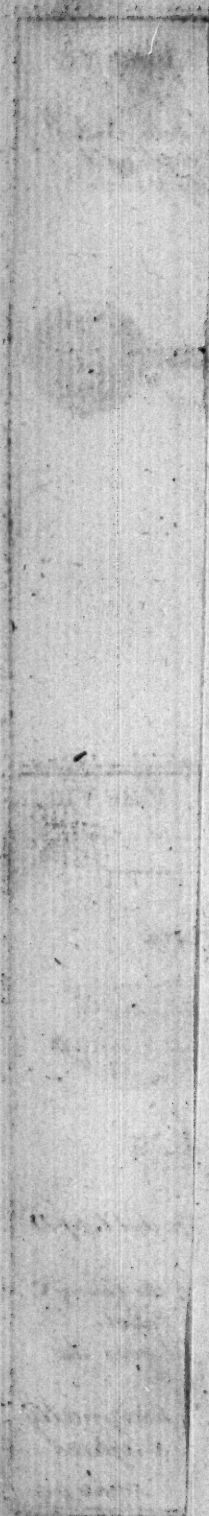
Fig. 4. p. 429.

AB. A Parallelepipedal Copper
Vessel.
B. It's Bottom with the Cavity C.
D. A conical Glass Vessel.
E. The same plac'd over the
water in C.
F. The same lying horizontally
G. The Flame of a lighted
Candle.

J. Wynde sculp.

Reimatic proposition 6 - mercury

This ~~which~~ which had been conjectured by theoretical chymists
has been lately opposed by the members of the Academy at
Petersburgh - they assailed themselves of the intense cold on
Dec^r 25 1759 - which had been further increased by the artificial
method known particularly by the mixture of Spr. Nit. with snow
Mr L^e's thermometer was sunk to the 24th degree
They then perceived that the ~~mercury~~ in the thermometer no longer
continued to mark the degrees of cold & suspected that it lost
its fluidity - Having broken their thermometer they
found the mercury actually consolidated - They repeated
this experiment upon other thermometers & found it
succeeded so completely that after having broken one
of these instruments, they extracted the mercury in
a solid state - they struck it with a hammer & per-
ceived it was flattened & extended like a malleable
Macquer - Fact. p. 394
mercury



fion, can deprive it thereof; thus when Mr. Boyle and M. Mariotte strongly compressed common air in a gun-barrel, and kept it long in a quiet place, yet upon opening the barrel, they found this air as elastic as at first; and M. Roberval, examining air, after it had been confined fifteen Years in the same manner, found its elasticity perfect (*k*). It will hereafter appear, that the elastic parts of air, deeply immersed in the pores of fluid, or solid bodies, being at length set free, and then uniting with others, exert the same degree of elasticity, which they thus seem to have lost, by giving no signs thereof; but when once released, they presently recover themselves, and produce extraordinary effects, merely owing to their elasticity: which shows, that neither time, nor rest, nor even their supposed concretion with animal, vegetable and mineral bodies, can destroy this wonderful property of the air. And we see by experiment, that these elastic particles of air, when existing separate, may be so united with other bodies, or remain so much at rest therein, as to afford no signs of elasticity for ages; and yet when they come to be loosened, and mixed with other particles of a like nature, they recover, or appear to have retained their whole elasticity: thus in the distillation of hartshorn, which may be kept for ages, we see a large quantity of air produced; whence it appears highly probable, that a single particle of air is not elastic; but that the elasticity of air arises from two of these particles, touching and repelling one another; so that if a parcel of these particles should be so far distant from each other, as to exert no repelling force, the whole of them would make no resistance to their compression, nor be capable of spontaneous expansion, till they come to be compressed so close, as that they might exert their repelling force. A single particle of air therefore would not be elastic; but elasticity depends upon the contact of several particles: We may, therefore, suppose the effects of elastic air to be immutable and eternal.

32. But how much soever air hath been compressed by weight, it hath always remained highly fluid, and capable of restoring itself so easily in all its parts, as perfectly to possess its former space; all these parts receding from one another as readily, as they came together. And as this has been the uniform success of all the experiments hitherto made, from 1 to 52000; it may be presumed true, that the fluidity of air remains unchanged in this large scale of rarification and condensation, so as never to become a solid by any force, either of cold, or pressure.

33. Mr. Boyle has demonstrated a considerable paradox, with respect to this elasticity of air, by shewing that the elasticity in every part thereof may, without any farther compression than it receives from the atmosphere, sustain the whole weight of an entire column thereof; and that this elasticity, in a very small quantity of air, so powerfully resists the pressure of bodies by its expansion, as to equal the power of the external weight (*l*): this he shews by the two following experiments. (1.) Take a barometer, with the mercury standing in it at the height of 28 inches, plunge its lower part into a close cylindrical vessel filled with mercury; this vessel being so contrived, that by turning of a cock,

E e 2

(*k*) See du Hamel Hist. of the Royal Academy of Sciences, p. 368.

(*l*) The rule of this dilatation, is, that the

spaces, possessed by the air, are always inversely as the forces whereby it is compressed.

all communication may be cut off between the external air and that small quantity contained in the vessel, above the surface of the mercury; the cock therefore being thus turned, so as to exclude the external air, no other air can press upon the surface of the mercury, except that shut up along with it; but now the mercury in the tube, still remains at the same height, as it did when the whole weight of the atmosphere pressed upon it; consequently this small quantity of confin'd air sustains the weight of the quicksilver, as much as that of the incumbent atmosphere: and if in this state the vessel be heated, the quicksilver gradually rises higher in the tube; for, as the included air cannot get out, it expands with heat, and thus presses the surface of the quicksilver, so as to raise it: and tho' but a very small quantity of air were contained in this vessel above the mercury, these effects will be the same. (2.) Again, let the vessel be almost full of quicksilver, only a little air remaining upon the surface; if now a small glass tube, open at both ends, be dipped into the mercury, so as no air can get in or out from the vessel, along the surface of the tube; then the air by means of the air-pump, being extracted from the tube, the quicksilver will rise into the barometer, to nearly the height of 28 inches, as if the whole weight of the atmosphere had pressed it (*m*). And this elastic power of the air deserves the particular regard of chemists, as it may certainly produce surprising and terrible effects in all their operations, perform'd by fire in close vessels, by compressing the subjects, bursting the glasses, &c.

*A small part
of air equal
in force to a
large one.*

34. A very small portion of air, therefore, under confinement may produce the same effects as a larger: thus if common air should be lodged in any compressible cavity, it may there not only sustain, but even repel the whole pressure of the atmosphere, upon coming to be rarified by fire, or freed from external pressure, so as immediately to expand or rarify, and equal the force of a larger quantity. 'Tis another law of this elasticity of air, that when air is condensed to a certain degree, it expands itself every way upon the application of heat; and the power of this expansion, arising from heat, is the same as if the air was condensed instead of being rarified; for example, if in the foregoing case and apparatus, the air in the vessel raises the mercury in the barometer 28 inches, and then the air in this vessel becomes twice as dense, it will raise the mercury to 56 inches, as Mr. Boyle has shewn: so on the other hand, if the former air be rarified to twice its bulk, upon the application of fire, and yet be confined within the same vessel, it will then also raise the mercury to 56 inches: and all kinds of experiments, made with the barometer and thermometer, manifest this to be true. And hence arise great and unexpected chemical effects, upon the application of fire to air, assignable to no other cause, and deserving to be carefully remarked.

*Air more ra-
rifiable by fire
than other bo-
dies.*

35. The rarification in air by heat is quicker than in any other known solid, or fluid body; an otherwise imperceptible increase of heat immediately producing a sensible rarification of the air in Drebel's thermometer: but the preceding history of fire has shewn these things so particularly, that they need not be repeated. We only add that, air is so prodigiously rarifiable by fire, that

(*m*) See Mr. Boyle's mechanical exper. vol. 1. part 2. p. 24.

that no limits have hitherto been found of its expansion; the heat of boiling water rarifies it $\frac{1}{3}$ of its bulk (n): but this rarification must needs be very great in a fire capable of melting iron; to which purpose consult the history of fire above.

36. We also find, that unequal quantities of air of the same density expand equally with the same degree of heat; and consequently, that these expansions of air of the same density universally correspond to the increase of heat applied; whence if the degree of expansion of any portion of air to a given heat be known, its degree of expansion may be determined in all other cases: many excellent particulars to this purpose may be found in the Memoirs of the Royal Academy of Sciences (o).

37. 'Tis also constantly found, that the more air is condensed by compression, the more elastic it becomes with the same degree of heat, and this nearly in a direct proportion of its density, as M. Amontons has discovered (p): so that air, greatly condensed, may acquire a strongly resisting force by a very small heat; whence if air could possibly be condensed to $\frac{1}{1000}$ part of its space, it might by the heat of boiling water be made capable of sustaining 29600 inches of mercury, as common air with the same heat sustains 37: this prodigious power may shew, that if the highest subterraneous heat be applied to air, compressed to $\frac{1}{1000}$ part of its bulk, in the deep parts of the earth, an almost incredible power would thence arise, so as far to exceed all the effects we are acquainted with; doubtless, the elastic power of the air would increase in a compound ratio of the increased density and heat applied (q): the converse also holds true; so that air, twice as much rarified, requires

(n) See *History of the Royal Acad. of Scienc.* anno 1699, p. 1101.

(o) *Ibid.* anno 1699, p. 173, and anno 1702, p. 1—5.

(p) See *History of the Royal Acad.* anno 1702, p. 1—5, and *Mem.* 155.

(q) M. Amontons has a discourse to prove that the weight and spring of air, with a moderate degree of warmth, may enable it to produce earthquakes, &c. According to the experiments of M. de la Hire, and M. Amontons, a column of air on the surface of the earth, 36 fathoms high, is equal in weight to three lines of mercury; and it is found that equal weights of air possess spaces reciprocally proportional to the weights wherewith they are pressed: the weight of air, therefore, which would fill the whole space possessed by the terrestrial globe, would be equal to a cylinder of mercury, whose base is equal to the surface of the earth, and its height contains as many times three lines as the atmospherical space contains orbs equal in weight to that of the 36 fathoms, whereof the experiment was made.

Hence taking the densest of all bodies, *i. gr.* Gold, whose gravity is about 14630 times greater than that of air in our orb, it is easy to compute, that this air would be reduced to

the same density as gold by the pressure of a column of mercury 14630 times 28 inches high, *i. e.* 409640 inches; since the bulks of air, in that case, would be in the reciprocal ratio of the weights, wherewith they are pressed; thus 409640 inches, therefore, expresses the height, at which the barometer must stand, where air would be as heavy as gold, and the number $2\frac{1}{2}\frac{632}{640}$ lines, the thickness to which our column of 36 fathoms of air would be reduced in the same place. Now we know, that 409640 inches, or 43528 fathoms is only the seventy-fourth part of the semi-diameter of the earth; and when you are past that, whatever matters there be, they must be lighter than air. It is not improbable, therefore, that the remaining sphere of 6451538 fathoms diameter, may be full of dense air, heavier by many degrees than the heaviest bodies among us.

Hence, again, as it is proved that the more air is compressed, the more does the same degree of fire increase the force of its spring, and render it capable of so much the greater effect; and that, for instance, the heat of boiling water increases this spring of our air beyond what it ordinarily is, by a quantity equal to one third of the weight, wherewith it

Air of the same density equally rarified by the same heat.

Dense air made more elastic by the same fire.

requires twice the heat to make it of the same elasticity, &c. as the above-mentioned author has shewn by experiments; whence we suppose, that air at the top of the atmosphere would scarce be rendered more elastic by the most violent fire, being already so highly rarified.

Condensed by cold.

38. The next thing observable in air, with regard to its elasticity, is, that it condenses by cold, as well as by increase of weight; so that an increase of cold always increases its density. The highest known degree of cold in the north of *Europe* is marked on the beginning of *Fahrenheit's* thermometer: hence by descending from the degree of boiling water to 0, we may learn the effect of cold in the condensing of air; but as artificial cold reduces the spirit of this thermometer 40 degrees below 0, hence we know the power of cold in increasing the density of the air, and find that no body in nature has its bulk more contracted thereby than air: when the atmosphere is 46 degrees hot by *Fahrenheit's* thermometer, if the heat be farther increased by 166 degrees, it will then be 212, the heat of boiling water, when air is rarified $\frac{1}{4}$; consequently, 166 degrees of heat expand air $\frac{3}{4}$, and by adding 40 degrees to 212, we shall have 252, for the difference between the highest known degree of cold and the heat of boiling water; within which difference the air is condensed $\frac{4}{5}$, or nearly $\frac{1}{2}$ of the whole. Upon the same footing, supposing the greatest heat of the atmosphere, in a free air, to rise by natural causes up to 90 degrees, which I believe seldom happens; in this case, the rarification or condensation of the air from the greatest natural cold to the strongest natural heat, may either increase or diminish to $\frac{1}{4}$. Hence it appears, how great a change may be made in nature by the air, as it surrounds bodies, or lodges in them, and receives the effects of natural heat and cold; the knowledge of which is of great use in the business of fermentation and putrefaction; the greatest difference between the most rarified air and the most condensed is determined by Mr. *Boyle* to be as 1 to 520000.

The spring of the air not destroyed by fire.

39. This elasticity is so peculiar to, and inseparable from air, as not to be destroyed by the most violent fire; for, if a spherical glass phial be kept in a glass-house furnace, till ready to melt, and then be hermetically sealed in that heat, and suffered gradually to cool; if now it be held, inverted, under cold water, and the end of the neck be carefully broke off, the water will be violently forced into it, and fill the glass, but so as to leave a bubble of true elastic air at the top; which shews, that the elasticity of the air could not be destroyed by so great a heat: and by comparing the weight of this phial, full of water, with that of the same phial, full of water and the air-bubble, we may learn the degree of expansion that air suffers by a heat wherein glass is ready to melt. And hence chemists may know, what changes they are to expect in their operations, when they treat bodies, full of air, with such a degree of heat: and tho' they seldom think of such things, yet it is of consequence that operators should remember them.

40.

it is pressed; we may infer that a degree of heat, which in our orb can only produce a moderate effect, may have a very violent one in such lower orb; and that as there may be many degrees of heat in nature, beyond that

of boiling water, it is probable there may be some, whose violence, thus assisted by the weight of the air, may be sufficient to tear asunder the solid globe. *Mem. de l'Acad. des* 1703.

40. Since therefore, after so high a degree of rarification, as from 1 to 520000, or more, and the corresponding numerous condensations, by the highest degrees of heat and cold, and this for so many years successively, the elasticity of air may still remain unaltered, 'tis probable that air is an unchangeably elastic, moveable fluid, constantly operating in, and open all bodies, by its own peculiar vibratory motion.

41. Having hitherto considered the properties of common air, as they relate to chemistry; we next proceed to examine into its contents, which are not only incredibly numerous and various, but also different in different parts of the atmosphere; so that it may properly be considered as an universal chaos, consisting of almost all kinds of corpuscles, confusedly jumbled together, and constituting one mass (*r*): we shall examine into them severally, in order to discover its real state.

42. Fire is a constant concomitant of the air, as is plain from our history of that element, and lodges in it in the same quantity as in all other bodies and in the *Torricellian vacuum*, as hath been already shewn by repeated trials with the thermometer; for, fire is plainly contained in *vacuo*, in air, &c. always alike, both in quantity and quality; whence we have a farther confirmation of this rule, that fire is co-extended with space. And since fire does not lodge in one body more than in another, it hence follows, that no one part of air will be hotter than another, on account of its containing different bodies; and therefore fire is always equally distributed in air, separately considered: on the other hand, numerous causes may arise, and be applied in the air, so as to collect fire, in a certain place, after a manner scarce to be determined; as we have shewn in the history of fire.

43. Water likewise is always present in air, so as scarce to be separated from it by art. As the perspirable matter is chiefly water, and as *Sanctorius* has shewn, that a man in health perspires nearly six pounds in twenty-four hours, how large a quantity hereof must go off into the air from the bodies of all animals? Plants also are observed to perspire, and Dr. *Hales* in his *vegetable Statics* shews, they thus discharge a prodigious quantity. Again, what a quantity of water is exhaled by subterraneous fires, &c.? Dr. *Halley* has computed, that the *Mediterranean* alone, in one summer's day, without the assistance of winds, exhales 52800000000 hogsheds of water (*s*). Since therefore, the sun and winds may still raise a much greater quantity; to which if we add all that arising from mists, dew, rain, hoar-frost, hail, snow, and nocturnal moisture, which might be collected in the space of a year, and add it to the water which rises into the air by means of the natural heat, in the same time; we shall find the whole capable of covering the surface of the earth to about 30 inches, as *Cruquius* has shewn in his meteorological tables; whence it is probable, that such a quantity of water is annually exhaled into the air.

We have also a sensible proof, that water is contained in every part of air by means of the air-pump; where, as the air is extracted, the remainder, being

(*r*) This Mr. *Boyle* long ago noted: 'Our atmosphere, says he, is a compound or aggregate of effluvia from such different bodies, as, tho' they all agree in constituting, by their minuteness and various motions, one

great mass of fluid matter, yet, perhaps, there is not a more heterogeneous body in the world. *Suspicion of Hidden Qualities in the Air.*

(*s*) See *Philos. Transf. Abridg.* Vol. II. p. 109.

being more rarified, becomes unable to support the water, which therefore, falls on the inside of the glass receiver, so as to render it opaque and cloudy; which not only shews us, that water is contained in all air, but also that the more rare the elastic part of the air becomes, it always proves less capable of containing water.

*In fixed al-
cali.*

44. But that water is copiously contained in all common air, appears evidently in the making of *oleum tartari per deliquium*; where, the dry fixed salt, being exposed to the air of any place, spontaneously dissolves by means of the water it attracts from the air, so as to afford a considerable increase of weight; which may easily be tried by the balance, and sometimes amounts to thrice the original weight of the salt employed: and this water so attracted by the air, may be obtained separate, by distilling the *oleum tartari per deliquium* to dryness. It is here remarkable, that the water, thus attracted from the air by the salt, performs the solution in a different manner than if common water was put to the same salt; for, the accession of the water in this experiment being successive and slow, it only dissolves that pure part of the alkaline salt, which is most soluble, and thus separates this part from the rest, which is more earthy; a thing that can be performed no other way: and hence, by repeated solution and coagulation, the whole quantity of salt may at length be converted into earth, and volatile substance, that does not appear to the senses; as was well-known to *Helmont* and other alchemists before him.

*Water makes
the greatest
part of com-
mon air.*

45. These considerations led me to discover that the air contained in a three-pint bottle, might hold water enough to moisten an ounce of salt of tartar, and increase its weight; and upon repeating the experiment, I found, that the water (here mixed with the air) being, perhaps, 850 times heavier than common air, must make up the largest part of the weight of this portion of air; for, if the 850th part of common air be water, the whole weight of the air must be owing to the water alone; whilst the other parts add little or nothing the weight, or perhaps do not gravitate at all. *M. Deventer* the famous writer upon midwifery, assured me he had made the same observation.

46. The following conclusions may, perhaps, be justly drawn from the premises. (1.) That the air is always in motion, tho' the place be ever so still, close, or subterraneous; otherwise the water, diffused in the air, cannot well come in contact with the salt of tartar; for, if a cubic foot of air, contains at most but $\frac{1}{850}$ of a pound troy of water, and deposits its water in the salt, contained in a close vessel, all the air must play about the surface of this salt, so that all its parts may successively touch it, and deposit the water they contain; or (2.) We must suppose, that the aqueous particles at one time diffused thro' the whole mass of the air, move in a certain time thro' it, so as successively to be in all the parts thereof, and at length meet in the salt contained within this air; or (3.) We must allow, that there is a real attraction between the salt and the water: and if attraction be here supposed the cause of the effect, the attraction must be allowed of an extensive nature; since the salt employed will attract thrice its weight of water; as three ounces of water must here possess at least two cubic feet and

a half of air: but to me it seems probable, from the experiments I have made, that all the three above-mentioned causes concur to produce the effect. It is observable, that in the preceding experiment, nothing elastic can be found in the oil of tartar *per deliquium*, and that the salt appears to attract the moisture of the air, without destroying its elasticity; whence, it should seem that the more the air is freed from aqueous vapours, the more elastic it becomes. In a clear dry season, the atmosphere is always heavier, and the water ascends higher therein; so that the atmosphere never contains more water than when, by reason of its dryness below, it seems to contain the least. 'Tis easy to imagine, that the higher the water ascends into the atmosphere, the more space it possesses, or the more it is rarified, till the particles come to be set so far asunder, as to lose the property of moisture; but if the barometer stands high, and thick fetid fogs arise, watery particles almost constantly float low, and are attended with gross, oily, saline exhalations; all which, at this time, are not equally mixed together. On the other hand, when the barometer stands low, and the weather proves hot and cloudy; the water, now falling lower in an uniform vapour, occasions a mist without rain; whence it appears, that an air, loaded with water, may often appear to be dry, clear and transparent; but when it contains less water, and this falls low, so as to collect together unequally, it may prove to be moist, thick, and dark; as we see in chemical distillations of water, where, if the glasses are well closed, while the operation is performed, we find no appearance of vapour; but if an opening be made, and the equality of pressure thus destroyed, the water exhales into the air in the form of vapour, rendering the contiguous bodies, and the air itself, moist, dark, and cloudy.

47. But if in a long continued summer's drought, the surface of the earth comes to be greatly parched with the heat of the sun, not only water, but also other less volatile substances, of an unctuous and saline nature, will thus be raised to some height in the atmosphere; tho' invisibly, so long as such exhalations are agitated by the sun's heat, which coming to lessen towards the evening, the air soon grows cooler; whilst at the same time, the earth, retaining the heat much longer than the air, still continues to breathe out hot exhalations; whence arises a white dense visible vapour, hotter below than above: this vapour appears, therefore, first in low, watery places, thence gradually diffuses itself, so as in the night to cover the earth with a mist, which is dissipated by the rising sun. This moisture, called by the name of dew, is a very compound substance; nor can we assert any thing, that will hold universally true of its peculiar nature: it must needs be a chaos, as it is a collection of all sorts of volatile particles, promiscuously jumbled together by the heat of the sun, acting upon the earth; it must also be different in different parts of the earth, according as different kinds of particles lodge therein. Thus, in large tracts of gravelly, or heath ground, which lie dry and high, it will be small in quantity, and almost totally aqueous; as in fat bituminous earths, near marshes, and standing waters, it is far different in quantity and quality, and prejudicial to health; whence, it is no wonder that chemists, in their analysing of dew, should find such different results, that scarce any two are agreed about them: certainly, they who seek for the spirit of life, the universal solvent, the mercury of life, the nitre and

steel of *Sendivogius*, in dew, seem not to take them right; it is more sober to say, that dew is of a subtile saponaceous nature, capable of supporting vegetables. Some dew, that had been collected in a certain part of the earth, has afforded a liquor, by distillation, which struck the colours of the rainbow upon glass, so strong as not to be effaced by friction, alkaline lixiviums, or *aqua-regia*; it also burnt like spirit of wine (*t*): again, some distilled dew, having been digested with a gentle heat for eight days, and then rectified six times over, till it was exceeding subtile, is reported to have broke three glass vessels successively, tho' it still remained perfectly insipid (*u*): again, some dew is described to be like a yellowish butter, that melts by being rubbed upon the hand, yet grows hard and dry with a moderate heat, being of a fetid odour, and to be found in pretty large lumps in the night, especially in the spring and winter (*x*). The nature of dew also differs surprisngly with the different seasons of the year, and the various successions of meteors; hence, exceedingly small seeds of vegetables, and invisible eggs of minute animals, with numerous other things, coming to be digested, fermented or putrefied therein, it must afford many very different productions by distillation; whence chemists have formed very odd opinions about it (*y*): we can only say that the greatest part of it is water; and that the other parts cannot be ascertained on account of their infinite variety.

Clouds.

48. 'Tis manifest that clouds chiefly arise from water, and that water, brought into an equable mass, is transparent; so that clouds must be formed from water, whose particles are beginning to come together, before they obtain their point of rest, and continue to roll about unequally; hence if water, floating in the air, rises higher and higher, its parts will at length rise so high, as to have no great power of union, but rather recede from each other: in this case, they will not constitute water, but the primary particles of water, which as they afterwards begin to descend, come closer together, unite, put on the form of water, and constitute clouds; whence, the higher water rises into the air, the clearer and dryer the season, and *vice versa* (*z*). That water rises to a considerable height in the air, we see by the mountains in *Carniola*, which tho' 10274 geometrical feet high, yet snow is found on their tops (*a*). Even the high mountain *Teneriff* is daily found to have clouds about it in the middle of the day, which turning to water, flow down so plentifully as to water the whole island, where showers are wanting (*b*).

Fine rain.

49. When the lower air is charged with water, the aqueous particles begin to unite, so as to form the minutest drops, or the finest rain, which generally falls thick, but with little force; as the smaller these drops are, the more surface they have in proportion to their bulk; whence their descent is the more hindered by the resistance of the air: but when water begins to

(*t*) See *Repub. of Letters*, Vol. I. p. 590.

(*u*) *Ibid.* an. 1708. p. 152.

(*x*) See *Phil. Transf. Abridg.* Vol. II. p. 143.

(*y*) *Ibid.* Vol. II. p. 141.

(*z*) See *AB. Erud. Lipf.* an. 1689. p. 552.

(*a*) An excellent astronomer of my acquaintance, says Mr. Boyle, who frequently took the

height of the clouds, very rarely found any even of the white ones, in fair weather, to be more than $\frac{3}{4}$ of a mile, and seldom above $\frac{1}{2}$ a mile, from the surface of the earth. *Boyle's Hist. of Air.*

(*b*) See *AB. Erud. Lipf.* 1691. p. 98.

to collect high in the atmosphere, so as to become heavier and fall thro' the air, thence gradually descending into more crouded spaces, they constantly unite with other aqueous particles in their way; whence proceed the largest drops of water we meet with in *Europe*, whose diameter is three lines; but in *Negro-land* 'tis often an inch (c): these drops are found to be the larger as they fall from a greater height, and *vice versa*; for, it is a constant observation, that the rain is small near the top of a high mountain, but grows larger and larger the nearer it comes to the bottom. And hence, the strongest showers happen in the summer, when water, by its rapid descent in rain, suddenly produces thunder, lightning, and storms; and then the drops of rain prove larger than in winter: thus much at least is certain, that rain in every part of the atmosphere is the finest, when it first begins to be generated.

50. When the air is saturated with water, and growing cold in the *Springs* night, dashes against the surface of high mountains, especially such as are formed into a long ridge, this dense and cold body, first, towards the north and east in the beginning of the night, and towards the south and west after midnight, is stopped, cooled, collected and turned into aqueous humidity; thence forms slender threads on the tops of the mountains, and constantly increasing in their descent, by uniting with the like fine streams, they increase, and thus make a perpetual dripping, that affords a large quantity of water, running down the sides of the mountain, so as to form rivulets, which sinking into subterraneous passages, constitute springs rising in other places; whence, according to the different depth of each spring from its vent, the jet of water must be different: and hence we may easily understand how the water of one spring comes to differ from that of another, in quantity and quality: and hence also, there are no springs, but where there are high mountains; an eminent instance whereof we have in the fortunate valley described by *Bernier*, in his account of the *Mogul's* country.

51. Wherever, therefore, such mountains and springs are found, the water *Rivulets and* running from the mountains, or continually discharged from the springs, *rivers.* forms itself into rivulets; which generally run a small stream at first, but being joined by others, they at length form a river; and this also increasing as it goes, may become of a very large size where it discharges itself into the sea, which it neither increases nor runs back from; the sea constantly exhaling as much as it receives: indeed, the rapid torrents of rivers fall into subterraneous caverns, and rise in other places; whence no rivers are found in flat countries, where there are neither mountains nor springs. Thus we see that mountains are wisely dispersed over the globe, in order to the collecting of water, and forming of rivers; and hence we find, that the course of rivers corresponds with the direction of mountains all over the globe. The discoveries of *Dr. Halley* deserve to be read, upon this subject, in the *Philosophical Transactions*. All these particulars should be known to chemists, who are frequently obliged to observe the difference there is between one water, as well as one air and another.

52. It does not appear from what is hitherto discover'd, how high water *Water every* may rise into the atmosphere; but thus much is certain, that there is no air *where con-* without *tained in air.*

F f f 2

(c) See *AE. Erud. Lipf. Sup. I. p. 425.*

without water, even on the tops of the highest mountains, where the air is constantly wet with vapours; and consequently the air applied in chemistry, will always contain water. It may perhaps be possible to extract the water out of a parcel of air contained in a glass; for, if hot and dry salt of tartar be put into a glass, the alkali might thus attract all the water from the air in that glass, whilst it remains close stopped: but such air as this cannot be used in chemical operations, because as soon as the glass is opened, moist air would immediately enter.

*Water turned
to ice at great
heights.*

53. We learn by experience, that the higher water rises into the air, the farther its parts recede from each other, and the colder it grows: for, we find by experiments, that in all the habitable parts of the globe, the heat is the greatest, *ceteris paribus*, on the surface of the earth; and a freezing cold is constantly found on the tops of the highest mountains, which are covered with snow. This holds true even under the equator and in the torrid zones. The degree of cold also increases, in proportion, as we rise from the foot of a mountain to the top; the increase being in proportion to that of the altitude. Hence, the water, rising into the air, and coming to the freezing height, must necessarily be turned to ice, unless all its particles should separate so as not to touch each other; but if, at this height, the particles of water, so dispersed, should by any means whatever come into contact, they must immediately begin to freeze into small icy flakes, floating about in the air; and if they should here happen to dash against the surface of any bodies in their way, they would constitute a fine hoar-frost, that would otherwise scarce be perceivable: whence, therefore, there is a space in the atmosphere, concentric with the earth, where the water of the air, when it arrives and unites, is constantly turned to ice. 'Tis however probable, that this water, being at first little united, can seldom freeze, but remains floating about, in its separate particles, till some cause happening to unite them, it is then turned into ice.

Snow.

54. The water of the air, in the space assign'd, growing heavier, by a larger quantity coming under less surface, and being now froze, it immediately begins to fall downwards into spaces fuller of water; where joining with other aqueous particles, it gradually forms larger masses of snow, or hail: and as there are many different causes, that may make these particles of water, which were dispersed in the upper air, suddenly unite in large quantities, 'tis easy to understand how these collections, coming into the freezing height of the atmosphere, may presently form considerable masses of snow, or hail.

Hail.

55. These masses, collecting together, occasion high small white clouds to appear, from the reflection of the sun in the air; thence falling with great velocity downwards, they seem suddenly to increase in magnitude, and dashing violently against others of the same kind, they make lightning, thunder, storms, showers, and hail, and this the stronger, the higher the places they fall from: and hence, in the summer-time, when the sky has long been clear, the lower air dry, the atmosphere heavy, and consequently the water raised high, the atmosphere then becoming light all on a sudden, the above-mentioned meteors are apt to appear; especially between the

tropics,

tropics, where a small cloud, appearing high in the air, portends a sudden violent storm. And it is highly probable, that as hail is always formed in the high cold parts of the atmosphere, and falling by its weight into a hotter region near the earth, is there melted, and forms violent showers, attending, following, or stopping thunder and lightning: but if they fall so quick, as not to be melted, they make violent storms of hail, capable of producing mischievous effects; and accordingly, we have accounts of hail-stones of a prodigious size (d).

56. Among the principal causes of these sudden-changes in the atmosphere, we may chiefly reckon the diminution of its weight; since, when air becomes lighter, water always spontaneously separates from it, so as to manifest itself, tho' it before lay concealed therein. Add to this, that the parts of the air, being frequently driven together from opposite quarters, thus suddenly unite the primary particles of water, which before floated separately. Perhaps also the different aspects of the planets may contribute to this effect; not to mention any thing of the change of heat and winds: all which are capable of producing the above-mentioned phenomena. *The causes of meteors.*

57. Numerous causes may conspire to raise up water, and mix it with the air; but a principle one is the sun, which the more perpendicularly its rays strike upon water, the more it raises. Another cause may be subterraneous fire, which is continually in action; for we find by observation, upon going down into deep mines, we soon come to a place where water does not freeze, but the degree of heat remains invariably the same; as the academicians of *Paris* have observed in the cave of their observatory: but upon going lower into mines, the heat is found to increase in proportion to the depth, so as at length to become suffocating, unless the air be refreshed by a current of water. We also see, in the winter-time, both the earth and water send out a warm vapour, upon breaking the ice, or digging into the frozen ground. Let no one imagine subterraneous fire a fiction, as if it could not there exist without air or fuel; for, this fire may arise, and be preserved, by the bare attrition of condensed air, without any other assistance; for, what heat will not air produce, when rendered 600 times more dense than common air, as it may be at the bottom of the deepest mines? And credible persons have affirmed, that air, compressed in an iron tube, has grown hot in such places. Doubtless, in the deepest parts of the earth, bodies are pressed with a prodigious incumbent weight, so as that a small attrition may produce a great degree of heat. As, therefore, the action of this fire is constant, it must produce a constant exhalation. In the next place, we must consider the great effects of culinary fire, used in all parts of the habitable globe, so as to raise water into the air from all kinds of subjects. Sharp frost raises a considerable part of ice into the air every moment, so as in a short time to carry off its whole bulk, as Mr. Boyle has shewn by statical experiments; and we frequently observe, that the violent cold of a hard winter wonderfully wears down all sorts of bodies, lessens, consumes, and disperses them into the air. Whatever physical cause may *Causes of the ascent of water.*

(d) See *Phil. Trans. Abridg.* Vol. II. p. 144.

so separate the particles of water from each other, as to make them exist single, will render them capable of floating in the air; as they now have a much larger surface in proportion to their solidity. We must also here consider the repelling power, which resists the contact of the surfaces of different bodies, and therefore continually increases as their surfaces increase; whence bodies, minutely divided, are less apt to descend by their own gravity; and hence we see the reason, why all the parts of water about the earth do not always fall at once out of the air. This repelling power seems also to be the cause, why the parts of water form themselves into a spherical figure about the air they contain; and when water, thus formed into drops, rises upwards, it expands as it rises, and in this form may remain at a great height in the atmosphere. But lastly, there is no cause, that carries off a greater quantity of water into the air than the wind, as Dr. Halley has shewn, and as I myself have seen by many surprising experiments; for, upon exposing a cylindrical copper vessel, full of water, in a storm of wind, I found an astonishing quantity evaporated in a very little time; whereas, when the wind was laid, but a very little exhaled in the same degree of heat: and hence violent winds follow upon showers, in order to agitate the water, before fallen, and carry it back into the air, lest it should otherwise stagnate and prove hurtful to vegetables. All these causes, therefore, conspiring together, are abundantly sufficient to raise water into the air, and keep it moving therein.

*The power of
elastic moist
air upon bo-
dies.*

58. Now supposing this elastic air, saturated with water, to act upon the bodies of men, vegetables, and minerals, we shall find it capable of producing many wonderful changes; its extreme tenuity, which makes it extremely penetrating, and fit to enter the smallest pores, joined to its perpetual mobility, and the determination it has to bodies by its gravity, render it productive of numerous effects, and occasion it to dissolve the salts, the saline and saponaceous matters contained in bodies (*f*): and as there are many such parts contained in most bodies; and as these are the principal instru-

(*f*) Mr Boyle assures us, that he has several times made a substance, consisting of a metalline body, of a texture so close, as to lie for many hours undissolved in a corrosive menstruum; yet this substance, that was fixed enough to endure melting by the fire, without losing its colour, would, when exposed to the air, be dissolved in a very short time, and have its superficial parts turned almost black. *Boyle's Hist. of Air.*

Air, 'tis observed, may have a notable operation on vitriol, even after a strong fire could work no farther thereon. The experienced *Zwelfer* informs us, that the colcothar of this mineral, made by a strong distillation, is not corrosive; and that no salt can be obtained from it soon after distillation, by the affusion of water. But, *says he*, if it be for some time exposed to the air, it will yield a salt, which is sometimes white, and sometimes of a beautiful

purple colour, and sometimes also a nitrous kind.

Mr. Boyle has even found the fumes of a sharp liquor to work more suddenly and manifestly on a certain metal, when sustained in the air, than did the menstruum itself, that emitted those fumes, on the parts of the metal it covered. And a chemist, who had been in Hungary and other parts, purposely to visit mines, assured him, that as to the ladders and other wooden works, employed in one or more of the deep Hungarian mines, those that were in the upper part of the grooves, near the external air, would by the fretting exhalations, be rendered unserviceable in a few months; whilst such ladders, pieces of timber, &c. as were employed in the lower parts of the mine, would hold good two or three times as long. *Id. ibid.*

instruments of their actions, it is easy to perceive, that the particular virtues of bodies are thus excited, so far as these depend upon the peculiar salts and saponaceous matters thereof. This principal change is wrought upon bodies by the water of the air, that it renders fixed salts, and other compound substances, volatile. It has long been found true in chemistry, that all native salts, treated in an open fire, and exposed to the air, run *per deliquium*, leaving a quantity of earth behind, that did not appear in the salt before; and if the liquor, thus freed from its first earth, be again evaporated to dryness, and exposed to the air a-fresh, more earth will be thus procured, till at length an incredible quantity thereof may be obtain'd; whilst the other principle, which before adhering to this earth, constituted the salt, is, by the repeated action of the water in the air, so loosened from its earth and separated, as to become volatile and vanish insensibly into the atmosphere. This surprising change does not only hold true of native salts, but also of the fixed kind made by calcination. So long therefore, as water is lodged in the air, and is agitated by heat, or by winds, it may produce great and unexpected relaxations in bodies, and in a manner exhaust many of them. Its effects in fermentation (g) are also considerable; and in the putrefaction of bodies, no cause has so great a share as a moist and warm air (b), which in a short time resolves bodies into corruption; and hence, physicians

(g) 'The air, Sir Isaac Newton observes, 'abounds with acid vapours, fit to promote 'fermentations; as appears by the rusting of 'iron and copper in it, the kindling of fire by 'blowing, and the beating of the heart by 'means of respiration.

'The above-mentioned motions, he adds, are 'so great and violent, as to shew that in fermentation the particles of bodies almost at rest, are put into new motions by a very 'potent principle, which acts upon them only 'when they approach one another, and causes 'them to meet and clash with great violence, 'and grow hot with the motion, and dash one 'another into pieces, and vanish into air, vapour, and flame.' *Opticks*.

(b) At *Guiney*, the heat, with the moisture of the air, are said to be so favourable to putrefaction, that the finest white sugar shall sometimes be full of maggots; and all their drugs, plaisters, &c. quite lose their virtue, and some of them grow verminous. 'Tis added, that in the island of *Jago*, they are obliged to expose their sweetmeats to the heat of the sun, and thereby exhale the moisture, they contracted in the night, which would otherwise have caused them to putrefy. *Boyle's Hist. of Air*.

Are not the moist particles, which float in the air, the cause of all corruption in bodies; since, according to *Acoffa*, every thing in *Peru*, (and the same is observed in *Egypt*;) where it seldom rains, continues long uncorrupted? Or,

is this resistance of putrefaction rather owing to the nitrous salt, wherewith the air of those countries abounds? *Boyle's Hist. of Air*.

Mr. Boyle gives us some singular instances of the effect of the air, hardly deducible from any of the known properties of this fluid. Dr. *Stubble* assured him, 'that the silks brought from *Jamaica*, will, if there exposed to the air, rot 'even whilst they preserve their colour; but if 'kept therefrom, hold both their strength and 'dye.' *Ibid*.

The same author was informed by a learned gentleman, 'that the air at *Brasil* had a great 'influence upon the colours of clothes, and even 'upon black; so that the sable taffety there worn 'by the higher rank, will, in a few days, become of an iron-colour; tho' when kept close 'in shops, it preserves its proper hue.' He also informed him, that at a place fifty leagues beyond *Paragua*, white people soon grow tawney, and as soon recover their native colour, by removing out of that quarter. *Ibid*.

The string of a viol has been observed to increase in the acuteness of its tone, by almost half a note, either a little before, or in rainy weather; and the same observer has likewise found, that putting false strings in his pocket for frets, they have been found true, when he came to use them. *Id. Ibid*.

If some *Egyptian* earth be taken up near the river, and carefully preserved from the wet and waste, it will be found, if duly examined by

physicians have observed, that the plague itself has been occasioned among animals by a long continued state of a hot and moist air. As, therefore, salts and saponaceous substances may be thus dissolved by means of the water in the air, and these be raised, conveyed, applied, and introduced into other bodies they meet with; hence it is plain, that the air may communicate the particular qualities of some bodies to others, and produce such effects upon them as could scarce happen from any other cause (i).

Other substances in the air.

59. We have hitherto considered the air as containing elastic parts, fire and water; we next proceed to examine what other substances continually float therein; and these we shall find are extremely numerous: for, as the earth receives all sorts of bodies out of the air, so the air, on the other hand, receives all sorts of bodies from the earth; whence there is a continual change, or a kind of distillation, of all things between the two.

The native spirit of vegetables.

60. Thus all the parts of vegetables ascend into the atmosphere; especially, their native spirits, which are every where breathed out from the surface of the earth, and fill the air: thus the adjacent shores send out the odoriferous exhalations of plants to a great distance upon the sea; and thus all the plants in nature exhale their spirits into the air, which returns them to the earth again, along with the water of the atmosphere (k): There is nothing more difficult to imitate by art than the fragrant spirit peculiar to vegetables; and these spirits, being set free from their tenacious binding sulphur, constantly become volatile, and float about in the atmosphere; whence many wonderful transformations proceed.

Fermented spirits.

61. On the other hand, vegetables, after fermentation, afford a long quantity of vinous spirit, which is not easily changed, but exhales spontaneously into the air; and if we remember that all these spirits, which were at any time produced upon the earth from any fermented vegetable, have exhaled into

by the balance, neither to increase, nor diminish its weight till the 17th of June; when it will begin to grow heavier, and continue to do so, as the river fills; whence they certainly know the state of the deluge, which doubtless proceeds from the moisture of the air. *Prosper Alpinus, Job. Varrot, &c. p. 69.*

The generation of animal substance from vegetable being the effect of putrefaction, as will hereafter be made appear; it seems, that the presence of the air is necessary for any piece of matter to commence animal. Thus the philosopher so often quoted, observes, that by keeping putrefied bodies in glasses hermetically sealed, and thereby secured from the contact of the external air, he had never been able to produce any insect, or other living creature; tho' he had sometimes kept animal substances, and even blood so included, for many months, and one or two of them for a longer time; and tho' these substances had a manifest change made in their consistence whilst they remained sealed up. *Boyle's Hist. of Air.*

Opening an exhausted receiver, wherein a

large quantity of verjuice with green, sour grapes, had lain included for three years, there appear'd no mouldiness any where; only the surface of the uppermost skins were a little discoloured with something, which by its taste, and appearance through a microscope, was suspected to be a kind of tartar. *Id. ibid.*

(i) *Phil. Trans. Abridg. Vol. II. p. 141. and Añ. Erud. 1683. p. 435.*

(k) 'A very ingenious physician told me, says Mr. Boyle, he learned upon the island Ternate, that the Dutch having agreed with the king, to sell almost all the clove-trees that grew there, in order to raise the value of their spice; such a change in the temper of the air happened thereupon, as shewed the exhalations which the blossoms afford, to be very wholesome; for soon after these fragrant trees were cut down, the whole island became exceedingly sickly; which my relator imputed to the corrosive and noxious steams of a volcano there, the ill effects whereof were formerly prevented by the aromatic effluvia of those spicy blossoms.' *Boyle Hist. of Air.*

into the air; we may suppose that the atmosphere itself is impregnated with spirit of wine. In whatever way, therefore, wine comes to be applied, its spirit must exhale into the air; which may furnish us with one probable reason, why fermentation is more successfully carried on in the open air. So likewise the parts of vegetables thrown off by the fire, which are another kind of spirit, ascend into the air and float therein (l).

62. Again, the native oils of vegetables ascend in time, or become totally *Oils*. volatile by the spontaneous heat of the air; for, there are few woods, wherein the oil is so closely connected with the earth of the subject, as long to withstand the force of the open air: and as for distilled chemical oils, they are much more volatile, and soon escape, so as to form unctuous exhalations in the atmosphere, that are readily inflammable; for, being now finely divided, so as to resemble alcohol, they may, as they float about in the air, be easily set on fire by the refracted or reflected rays of the sun; especially, if before heated by the attrition of the clouds. All vegetable oils, therefore, may be raised into the atmosphere, and fall back again, as well as the vegetable waters and spirits, at their proper times, in a fat moistening dew, so as to fertilize the earth, especially in the warm seasons; for, the rain in summer is more fertilizing than in winter.

63. All kinds of vegetable salts, whether procured by crystallization, *Salts*. fermentation, putrefaction, or calcination, sooner or later become volatile, and fly into the air, after being once released from their fixing earth.

64. Even the earth it self, which makes the fixed element of plants, may *Earths*. be rendered so fine, as to become volatile: thus, foot we find affords by distillation no inconsiderable proportion of earth; yet smoak, which is the matter of foot, floats freely in the air; and strong winds tear up, and carry away the sands of *Egypt* and *Lybia*, and the ashes of *Ætna* and *Vesuvius* (m); nay, the seeds of plants, and shoals of little fish (n) have been carried thro' the air: whence, 'tis plain, that all the elementary parts of vegetables may be carried into the air, and mixed with it (o).

65. 'Tis obvious, that the perspirable matter of animals goes into the air, *Animals, and* as well as their excrementitious parts (p); nay, even the vast bodies of *their eggs*. whales, elephants, &c. by lying exposed in a warm air, will in a little time be almost totally exhaled (q). 'Tis here worth considering, that the impreg-

nated

(l) In places where much wood is burnt, numerous particles of volatile salt may easily be dispersed through the adjacent air; for wood-foot, which is only that small part of the smoke, which adheres to the chimneysides, affords a volatile, saline spirit in great plenty; and not readily, unless by the scent, distinguishable from that of urine or hartshorn. *Boyle Hist. of Air.*

(m) *Phil. Transf. Abr.* Vol. II. p. 142. & 144.

(n) *Phil. Transf.* No 21. p. 377.

(o) *Phil. Transf.* No. 168. p. 911.

(p) My Lord *Sandwich* and two gentlemen of his retinue assured Mr. *Boyle*, 'That the common report, as to there being no necessary-houses at *Madrid*, was true; and that though they always make a jakes of their

streets over night, 'tis not easily discoverable by the scent next morning. *Madrid*, however, his Lordship said, had a more offensive scent than any city he knew: But they all agreed, that the place wherein the Ambassador's family constantly made water, had no scent of urine; and that they frequently observed, both the dogs and cats, which lay dead in the streets, afforded no offensive smell.' *Boyle Hist. of Air.*

(q) The putrefaction of animal substances may supply the air with volatile salts, since some putrefied urine will, without distillation, afford saline and spirituous parts; which, by their scent, &c. discover themselves to be volatile, even while swimming in their own large quantity of phlegm. *Boyle Hist. of Air.*

nated eggs of animals may be carried through the air. As *Rbedi* had shewn, that all insects were produced by the action of male and female; and *Leuwenhoek*, that the male seed inserts the embryo in the female egg; and Mr. *Boyle*, that these impregnated eggs do not prove prolific without the assistance of the open air, I tryed the following experiment. I first boiled a piece of flesh in alcohol, then dipped it in clear oil of turpentine, and afterwards hung it up in a moist warm air, where I judged no little creatures could come near it; this flesh, in a short time afterwards, I found full of little mites, which eat up the juices remaining in the flesh. The eggs, from whence these little creatures were produced, must needs be convey'd to it through the air, in which the flesh hung. We often see trees blighted, in a warm spring, and swarming with numerous vermicular animalcula, bred almost instantaneously from invisible eggs brought by the winds; and in *Negro-land* showers frequently happen, which make the body tremble with cold; the drops of this rain are an inch in diameter, and if they touch the skin, they eat it; but if they fall upon the clothes, they produce live worms and moths (r). There are many instances of the like nature, which may put a chemist upon his guard to examine, whether some uncommon effects upon the subjects of his art are not sometimes owing to the eggs of animals, conveyed by the air; at least, this cause should be regarded before others are assigned. The nature and properties of the air are very necessary to be observed, as well by physicians and philosophers, as chemists.

*Fossils in the
air, viz. salts.*

66. Even fossils themselves are found in the air; thus the most fixed among fossils salts (s), if spontaneously dissolved by the water they attract from the

(r) *AA. Lips. Supp.* Vol. I. p. 425.

(s) One principal sort of these effluvia in the atmosphere, I take to be saline, which float variously among the rest in that vast ocean; for, they seem not to be equally mixed therein, but are to be found of different kinds, in different quantities and places, at different seasons. The arguments, which shew that subterraneous effluvia in general, ascend plentifully into the air, prove the same of saline ones in particular; since, it has been demonstrated, that immense quantities of common, nitrous, aluminous, vitriolic, and perhaps other salts, rise among the various exhalations of the terraqueous globe. The quantity hereof may be greatly increased in several places by such vulcanos as have open vents; by the smoke of the common culinary fires, &c. *Boyle Hist. of Air.*

The air of some places may, besides the simple salts already mentioned, contain some compound ones; it being shewn, that particular saline spirits may meet and join together therein; as also, that two liquors may be so ordered, that one of them shall never, of itself, afford any thing in a dry form; yet its spirituous effluvia, meeting with those of the ether, produce a dry, volatile and saline body, which

the mixture of the liquors themselves would not.

In places abounding with *Marcasites*, says Mr. *Boyle*, 'there is a fretting vitriolic salt largely dispersed thro' the air, which has been observed to rot the hangings of rooms, and other furniture; and to lie upon the surface of the ground in a whitish effluence, after the sun had heated the moist and blackish mould wherein it lay.' *Ibid.*

Besides these saline substances of a determinate species, there are possibly at certain times and places, other corpuscles in the air of a saline nature, but not reducible to any particular kind, which we therefore call *anonymous*. We have observed in old glass windows, belonging to high and ancient buildings some panes corroded, as if they had been worm-eaten; which seems to argue, that sharp and fretting particles had been carried thither by winds, whereto that glass was exposed; tho' none of the salts before-mentioned have the faculty of corroding common glass. *Ibid.*

The many saline effluvia that rise with the other subterraneous steams, cannot, all of them, be well supposed of a simple and un-

the air, and afterwards digested by a long continued putrefactive heat, then committed to a strong distillation, if the fixed remainder be calcined in a strong open fire, and again dissolved in the air, they at length become totally volatile. So again, when these fixed salts are distilled with sand, bole, &c. in a strong heat, large quantities of such salts are annually converted into volatile acid fumes or spirits; by which means the air it felt may in a manner become poisonous, and destructive to the bodies exposed thereto. The bare addition of oil of vitriol to sea-salt, or nitre, instantly converts these fixed salts into fumes, that can scarce be confined: whence the air becomes impregnated with them to a considerable distance; and there are numerous ways of producing these effects, though the art of thus changing salts was not known before the time of *Glauber*; nor do we at present know all the ways, which nature may use for converting fixed bodies into volatile: the pernicious fumes rising about mines (1) sufficiently manifest that salts may thus naturally be dispersed in the air, and consequently, that there are secret

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means

‘uncompounded nature. A very intelligent acquaintance of mine, who visited a vulcano in *America*, told me, that before he came near enough to see the fire, or to be very sensible of its heat, the skin of his face was so corroded, and the colour of his hair changed, by the exhalations, as to prevent his nearer approach thereto.’ *Ibid.*

‘At *Fablan* in *Sweden*, noted for one of the best copper mines of that kingdom, the mineral exhalations affect the air so, that their silver coin is frequently discoloured, and sometimes turned black thereby; tho’ close tied up in several purses, and locked up in strong chests. The same effluvia manifestly affect brass, and to such a degree, that there is no possibility of keeping their utensils of this kind tolerably clean.’ *Ibid.*

‘A virtuoso, who possessed a piece of ground, wherein ran several veins of different metals and minerals, told me he had frequently seen pillars, as it were, of fumes ascending thence like smoke; some whereof had no scent, some an ill one, and some again a good one; tho’ the latter happen’d but seldom.’ *Ibid.*

‘Copper that has been long exposed to the air, contracts a rust by the saline particles of that fluid, gradually fastening themselves in such numbers to the surface of the metal as to corrode it, and produce a substance of the colour of verdigrease; which is a factitious body, made of the same metal, corroded by the sharp corpuscles of vinegar, or of the husks of grapes.’ *Boyle Hid. Qual.*

‘Tho’ *Morocco* be an inland town, seated in a very hot climate, where the soil is usually dry; yet I am informed, that the nocturnal air proves exceeding damp and piercing, so as presently to produce rust upon such iron

‘instruments as lie naked therein.’ *Id. Hist. of Air.*

‘In the most southern parts of the *English* colonies, the great guns are so subject to rust that after lying a few years in the open air, large cakes of *crocus martis* may, with a hammer, be easily beat off them; whilst others that lay sunk in the salt-water, during the same time, are by no means so much affected. Hence, as dew is only steams of the terrestrial globe, the phenomena that manifest its power to work on solid bodies, may help to shew, how much the air abounds with saline and subtile parts.’ *Ibid.*

(2) What effect the neighbourhood of mines have, appears from Mr. *Boyle*: A famous chemist, who livid in a country abounding with mines of vitriol, assured him, that he had found the oaks growing over them to be remarkably more solid and heavy, than those trees elsewhere are; upon which Mr. *Boyle* observes, that the parts of some minerals are capable of insinuating themselves very plentifully into the pores of growing vegetables, without being really subdued by what the philosophers call the concocting faculty of the plant; but instead of being assimilated by the vegetable, retain their own mineral nature; and upon the recess, or evaporation of the juice that served them for a vehicle, sometimes discover themselves to the naked eye. He adds, he has seen a piece of a vine, that grew not far from *Paris*, which being broken, a multitude of the internal pores of the root, and a part of the trunk also, appeared to be stuffed with corpuscles of a marcastical nature; as was plain by their colour, their shining lustre, and their weight. *Causes of wholesomeness, &c. of the air.*

means used by nature for this purpose, though they are only applied in particular parts of the earth, where a proper matter is found; and then too, they only rise to a small determinate height in the air: whence, according to the ancient adepts, the air is said to be divided into certain strata, each containing a particular kind of exhalation, or vapour. Hence it is plain, that water, heat, digestion, solution, exsiccation, distillation, calcination, uction, mixture, union and separation may render fixed fossil salts, volatile, and intermix them with the air.

Sulphurs.

67. The part called sulphur, in fossils, totally flies into the air upon burning, whilst the saline acid part resolves into a suffocating invisible vapour, or gross black fume: even sulphur itself, when reduced to a fine powder by heat, rises into the air; and if mixed with other bodies, it often becomes surprizingly volatile. Chemists have remarked many ways, whereby nature, or art changes sulphurs, so as to make them fly into the atmosphere, and carry other bodies along with them. Unctuous, fetid, suffocating vapours often prove fatal to the miners; these vapours catch fire at the flame of a candle, so as suddenly to burn with great fury and danger; and it is certain, that these fumes consist of arsenic, orpiment, cobalt, or the sulphurs of antimony, bismuth, &c. and we read of sulphureous showers attended with thunder and lightning, that burnt, so as not to be extinguished by water (u), &c.

Metals.

68. Metals themselves have been so far changed, as to rise into the air in form of a volatile fume; quicksilver in particular flies away invisibly, with a heat of 600 degrees; and if the air, impregnated therewith, comes in contact with the human body, it proves surprizingly penetrating, and presently raises a salivation: nay, this fume of quicksilver carries up with it something from metals; as we see in the distillation of lead and tin with mercury. Iron, copper, tin and lead, being treated in a violent fire, also become volatile of themselves, and dissipate in part into the air. Lead in cupelling carries off a great part of the imperfect metals. So when cobalt, arsenic, or the like sulphurs are intimately mix'd with gold or silver ores, these ores lose a large proportion of their metal, which is render'd volatile in the fire, and which might be saved by a gentle calcination, and the use of fixing powders; whence it appears that large quantities of gold and silver may be dispersed in the air. It may seem strange to talk of volatile gold, but we learn from chemistry, that if mercury-sublimate be ground with the calx of gold, and distilled, by the retort, with regulus of antimony, the body of the gold will rise, and come over perfectly volatile in the form of a purple oil: and nearly, all the metals may be render'd volatile in the fire, by means of a proper mixture of sulphur, calcined vitriol, and sal-ammoniac. No wonder, therefore, that, on a clear day, fumes should suddenly arise near mines capable of extinguishing a lighted torch, as Mr. Boyle mentions; since, the densest bodies may be thus raised in the form of fumes into the air; though it be hard to determine what the particular bodies are. But there is frequently another cause, why the air is impregnated with metallic matters; viz. its abounding with salts and sulphurs; for, as we have above shown, that the air is full of these salts and sulphurs, which are capable of dissolving and carrying

(u) *Novel. Literar.* Ann. 1684. p. 63.

carrying off metals, 'tis easy to perceive how the air may suspend and carry about metallic particles in it. Thus we see, that lead, copper and iron are by the contact and motion of the air quickly turned into flowers, rust and scales; or ceruse, verdigrease and calx; which, being brought into fine powder, may easily be carried by winds into the air. Gold, silver and tin seem to be less acted upon in this manner, because their saline, volatile, acid solvents are scarce found in the air, remote from the laboratories of chemists; but in *America* the air is so corrosive, as to consume the tiles off the houses, and almost all stony and metallic bodies (x); which is generally allowed to be the case in the air of *Bermudas*: and to this cause is probably owing the effect constantly observed by miners; viz. that the ores, after being dug up, and exposed to the air, are thereby affected in a singular manner, on account of the metallic particles lodging therein. So likewise we frequently see marcasites, or vitriol-stones, and other exhausted metallic matters, so chang'd by the air, in which they lie, as to increase, ripen, renovate and become rich in metallic matter (y): hence the air seems to be the great sower of all things,

(x) An experienced mason told me, that *Salisbury* cathedral is built of *Purbeck* stone, which gradually becomes softer, and moulders away in the air; that the same is observed of *Blackington* stone, tho' kept from the wet: but what comes from *Painfwick*, within four miles of *Glocester*, tho' soft and pliable at the first, will, by lying in the air, acquire an hard, yellowish, glassy crust, like marble; which grows the more durable for being often washed. *Boyle, Hid. Qual.*

(y) Mr. *Boyle* causing a solid marcasite, hard as stone, to be broken, that the internal and more shining parts might be exposed to the air; he found, that tho' this was done in a room where a good fire was usual kept, so that the marcasite was not only sheltered from the rain, but kept in a dry air; yet after a while, there appeared on this glittering part, an efflorescence of a vitriolic nature. Afterwards meeting with a ponderous dark-coloured mineral, which at the very first breaking discovered to the eye no appearance of any salt, nor so much as any shining marcasitical particles; he found, that a large quantity of these hard and heavy bodies being kept exposed to the air, even in a room that preserved them from rain, tho' probably they had lain many ages intire under ground, in the hill where they were found; yet, in a few months, by the operation of the air upon them, they were in a great part crumbled to a powder, exceeding rich in copperas. Nay, having laid up some of these stones in a room, where he constantly kept a fire, and in the drawer of a cabinet, which he did not often take out to give them fresh air, most of them were covered with a large efflorescence;

which, by its conspicuous colour, between blue and green, by its taste and fitness to make in a trice an inky mixture with an infusion of galls, sufficiently manifested itself to be vitriol.

That the earth, or ore of alum, robbed of its salt, will in tract of time recover it, by being exposed to the air, we are assured by the experienced *Agricola*. And Mr. *Boyle* observes, that some kind of lime in old walls, and moist places, has, in time, gained a large efflorescence, very much of a nitrous nature; as he was convinced by having obtained saltpetre from it, upon barely dissolving it in common water, and evaporating the filtered solution.

It may seem doubtful, whether the salts appearing in the fore-mentioned cases are really produced by the operation of the air working as an agent, or concurring as an ingredient; or whether these saline substances proceed not from some internal thing, analogous to a seminal principle, causing in them a kind of maturation of some parts; which being once ripened, and perhaps assisted by the moisture of the air, disclose themselves in the saline concretions: as in the feculent or tartarous part of wines, there will, in tract of time, be generated or produced, numerous corpuscles of a saline nature; that give the acid taste we find in tartar, especially in that of rhenish wine.

It may also be suspected, that the salts found in marcasites, nitrous, and aluminous earths, &c. are made by the saline particles of the like nature, that, among multitudes of other kinds, swim in the air, and are attracted by similar particles yet remaining in the terrestrial

things, as being rich in all kinds of materials, and committing the elements of bodies to the earth, from whence it before received them; thus generating most substances, though rather in the manner of a revolution than new production: and thus, dew has afforded a liquor by distillation, which struck the colours of the rainbow upon glass, so deep as not to be discharged by *aqua-fortis*, oil of tartar, or strong rubbing; and this, though the liquor it self was so subtle, as to burn like spirit of wine (z): this effect is extremely like that of a metallic tincture upon glass (a).

The internal
nature of the
air.

69. Thus much may serve to shew, what notion we should entertain of the air; which is to be held as a chaos of all sorts of bodies mixed together; since, particles of all sorts of bodies float therein, so as to produce all those wonderful

terrestrial bodies, which are, as it were, the wombs of such minerals; as a spirit of nitre will with fixed nitre, and some other alkalies, compose salt-petre: or else, that such aerial salts, assisted by the moisture of the air, soften, open, and almost corrode, or dissolve the more terrestrial substances of these wombs, and thereby sollicit and extricate the latent saline particles; and by their union with them, compose those resulting bodies that resemble vitriol, alum, &c.

But tho' these considerations should be thought sufficient to rescue the production of salts from the effect of any hidden properties of the air, we have others which abundantly evince the existence of such properties: as the air's access rendering antimonial medicines not only emetic, but also disposed to produce heart-burnings, faintings, &c. none of which, when kept from the air, they do at all tend to promote; its affording strange prognostics of plagues; as that of the person mentioned by Mr. Boyle, who for three successive plague-seasons had an odd tumour formed in his groin, about three months before the plague began; by which he constantly foretold its approach: with infinite others to be met withal in naturalists, chemists, &c. as Zwelfer, Boyle, Cardan, Scaliger, Diemerbroeck, &c.

To account for the origin of such properties of the air, Mr. Boyle observes, that as we cannot pronounce so much as negatively whether the libration of the moon, and the motion of the sun, and perhaps of some of the other planets, about their own centres, and consequently their turning several parts of their bodies to us, may not have an operation upon our atmosphere; so, for ought we know, there may be in those vast internal parts of the earth, whose thin crust has been here and there dug into, considerable masses of matter that have periodical revolutions, accensions, e-stuations, fermentations, or in short, some other notable commotions; the effluvia where-

of may produce effects yet unobserved on the atmosphere, and on some particular bodies exposed to it: tho' these periods may, perhaps, be altogether irregular, or have some kind of regularity different from what one would expect. Thus the sea has those grand intumescencies we call spring tides, not every day, nor at any constant day of the month or week, but about the full and new moon; and these spring-tides are most notably heightened, not every month, but twice a year; at or about the vernal and autumnal equinoxes: which observations are not near so ancient, and so well known, as the daily ebbing and flowing of the sea. The Etesians of the ancients we do not now insist on, nor the observations of the elder inhabitants of the *Caribbean-Islands*, who, when the Europeans first resorted thither, had hurricanes but once in seven years; afterwards they were molested with them once in three years; of late they have been troubled with them almost every year: and a physician who had lived there since, assured us, he had scarce observed them to succeed one another in less compass than of two months. In which instances, and in several others, it may be noted, that in the changes which happen to great quantities of matter, nature seems to affect something of the periodical, but not in a way that appears to us regular. We may add what *Varenus* relates of those hot springs in Germany, which he calls *Therma piperina*, that they annually begin to flow at certain seasons; the former about the third of May, and the latter near the middle of September; from which time they rest till the following spring: to say nothing of numerous other periodical springs which flow, some of them so many hours, and some so many days, and then rest as many, alternately. See Boyle Abr. Vol. III. p. 89, 90, &c.

(x) *Repub. de Lettres*. Vol. I. p. 590.

(a) *Phil. Trans. Abr.* Vol. II. p. 143.

wonderful effects, which depend upon the efficacy of particular bodies: whence numerous phænomena arise in the air, which are no where else to be met with; particularly the meteors. Thus there must be magnetic bodies in the air, which by their attractions, repulsions, &c. every where produce surprising effects. To illustrate this by an example, if you hold an open glass in one hand, full of alkaline spirit, and in the other a glass of the strong spirit of nitre; and first keep them at a distance from each other; nothing observable will appear; but as soon as you approach these glasses to each other, that the fumes, arising from each, may meet together, a little cloud will immediately be formed upon the meeting of the acid and alkali in the air: so, if an amalgam of tin and quicksilver be distilled, in a retort, with spirit of sea-salt, it affords a liquor, which, being kept in a close glass, lies quiet; but if opened, presently rises in a thick fume, tho' the liquor had been made many years; and nature abounds with the like examples: but we do not know what kinds of salts may reside in the air, nor with what properties, they may be endued (b): 'tis hard to assign what spirits, or oils, may float therein; and consequently, what effects may arise from their peculiar natures. We see what a prodigious effect instantly arises, upon mixing the distilled oil of sassafras with *Glauber's* spirit of nitre; an effect scarce to be shewn by any other experiment: and if any of these substances should float in the air, and mix together, wonderful appearances might be produced. But the comets, the meteors, the aspects of the planets, and perhaps of the fixed stars themselves, may occasion such phænomena to happen rarely: for these celestial bodies may act powerfully by means of their attraction and repulsion, their light, heat and cold; and again, with respect to the effluvia, which they generate and send forth (c). And in all these respects, the air may be different in different

(b) Mr *Boyle* proposes a method of determining, what the particular species of salt is, that predominates in the air of any place, or at any time. This, he thinks, may be done by a sort of magnets, or attractives, i. e. bodies fitted to detain and absorb, or at least likely to be affected by the particular salts, supposed chiefly to abound: For instance, if we suspect the air to be impregnated with nitre, lime, or the like bodies, which imbibe, or retain such a saltiness; dyed cloths, or silks of such particular colours, which fade or tarnish with nitrous spirits, may be exposed thereto: Where vitriolic effluvia are supposed predominant, proper preparations of sulphur may be suspended, to try, whether they will acquire a blackness: in other places, guesses may be made, by spreading on the clean ground white linen cloth, well freed from soap or lee, and observing, after it has lain a considerable time, what discoloration it has suffered, and what saltiness it has imbibed, either from the ascending steams, or falling dews.

Or, you may find some one body capable of being affected by several aerial salts, in such different manners, as to discover which kind

produced there respective changes. *Boyle, Hist. of air.*

(c) Besides the alterations in respect of heat and cold, drought and moisture, to which our atmosphere is liable from the heavenly bodies; very great philosophers have suspected that there may be other more immediate and specific ones. Sir *Is. Newton* supposes, that the vapour which makes the tail of comets, coming to be exceedingly rarified and agitated in their approach toward the sun, may be driven and diffused thence through the heavenly spaces, and so come to be attracted by the several planets within those spheres of activity it chances to be thrown. Thus mixing with their atmospheres, says he, it may afford them a fresh supply of water, to defray the continual expences thereof in vegetation, putrefaction, &c. He adds, that he suspects the finest, purest, and best part of our air, that, in effect, whereby life is sustained, to be principally derived from the comets. *Phil. Nat. Princ. Math.* 1. 3.

Mr. *Boyle* suggests, that even the sun, and other celestial bodies, may have influences here below distinct from their heat and light; and that

ent places; as also, with regard to the soil, or part of the earth, over which the air is found; for, as the earth produces different substances in different places, the vapours and exhalations will thence be different, and consequently impregnate the air differently, as we find by numerous experiments (*d*);

and that the subtle effluvia thereof, may reach as far as our atmosphere, and mix therewith. Every planet, says he, has its own proper light, distinct from that of the others; which is either a bare quality, on which supposition its utmost use and design is only to illuminate; or else all light is attended with some peculiar virtue, or tincture; in which case every light must have its peculiar property, tincture and colour, its own specific virtue and power; in which the planets all differ from each other. Thus, adds he, the sun not only shines on all the planets, but, by his genial warmth, calls forth, excites, and raises the motions, properties, and powers, peculiar to them. Whence; according to the angle they make with that grand luminary, and the degree wherein they are enlightened, either by its direct or oblique rays, in a near or remote situation in respect of the earth; the effects of the powers, virtues, and tinctures proper to each, must be more or less perceived by us. *Hist. of Air.*

—As the other planets, so also our earth, is not only enlightened, warmed, cherished, and made fruitful by the influence of the sun; but it hath, moreover, its proper magnetical, planetary force, awakened, fermented, excited, and agitated thereby; which it sends back with the reflected light of that luminary. By this means also, the seminal dispositions, odours and ferments, lodged in particular regions and parts hereof, emit and diffuse through the air either the kindly and grateful, or malignant, congealing, and putrefying qualities. Hence, though the temper, disposition, and general qualities of the air, may be assigned, according to the motions, influences, and aspects of several superior planets; yet the particular healthfulness and unhealthfulness of places; the bad dispositions of the air, whether in the evenings, nights or mornings; in some places more than others; excessive moisture, great winds, droughts, or seasons peculiar to a country; should chiefly be ascribed to those odours, vapours and exhalations, that, by the action of the sun, or other planets, are forced from their particular seats in the planets themselves, into the open air. *Id. Ibid.*

(*d*) In an express treatise on the *wholesomeness and unwholesomeness of the air*, Mr. Boyle makes appear, that it depends principally on the impregnation the air receives from subterraneous effluvia, a cause generally overlook'd

by physicians; of which he distinguishes divers kinds; *viz.* ordinary, which are almost constantly sending up; extraordinary, which rise but at certain times. These, again, if they come at stated seasons, he calls *periodical*; if uncertainly, *fortuitous*, or irregular.

In general, tho' the wholesomeness of the air in some places may be chiefly due to the wholesome expirations of subterraneous bodies; yet is the air depraved in far more places than it is improved, by being impregnated with mineral expirations. Indeed, among the minerals known to us, there are many more noxious than wholesome; and the power of the former to do mischief, is more efficacious than of the latter to do good; as we may guess by the small benefit men receive in point of health, by the effluvia of any mineral, or other known fossil, in comparison of the great and sudden damage that is often done by the expirations of orpiment, sandarac, and arsenic.

Among the various sorts of particles where-with the atmosphere is replete, some, he shews, may be so small and solid, or so conveniently shaped, as to enter many of the numerous orifices of the minute glandules of the skin, or at other pores thereof. Thus, tho' neither paper, nor a bladder, be pervious to the elastic parts of the air; yet may either of them be easily penetrated by other corpuscles of the atmosphere; and that excellent author has prepared a dry body, which being inclosed in either, would, without wetting or discolouring, or any way sensibly altering them, pass in a trice thro' the pores thereof, in such plenty as to exert a manifest operation on bodies placed at some distance therefrom.

This is confirmed from the sudden check almost every summer given to the plague at *Grand Cairo*: for, since morbid causes operate more effectually than curative ones, it seems more than probable, that exhalations ascending from under ground, may produce pestilential fevers, and the plague itself; since the corpuscles which impregnate the *Egyptian* air upon the swelling of the *Nile*, put a speedy stop not only to the contagion, but to the malignity of the plague, assisted even by the summer's heat, which there is excessive.

'Tis very probable, that most of the diseases, which even physicians call *new*, are caused, either principally or secondarily, by subterraneous steams.

Indeed

and hence it is, that some experiments succeed in certain places, and certain dispositions of the air, but not in others. A great diversity also arises in respect of the soils in different places, as they are inhabited by men, cultivated, fed upon by animals, manured and exercised by various arts; whence almost all kinds of bodies come to rise into the air; and whence numerous particulars may happen in one place, that do not happen in another. Thus, for example, if oil of tartar *per deliquium* be made in a laboratory, abounding with the fumes of vinegar; this, upon evaporation, will be found to be a regenerated tartar, flowing like wax in the fire, instead of salt of tartar: but if the experiment was to be repeated in another place, not abounding with the fumes of vinegar, a very different substance would be obtained. Many examples might be produced to the like purpose; whence we may understand how much the air of a certain place may be altered by earthquakes (e), &c. so as to become very different from what it was before. Thus, history informs us, that certain parts of the earth have become uninhabitable on account of noxious vapours rising after an earthquake (f); and hence inundations

Indeed there may be noxious minerals in a country, without being often able to produce pestilences: they may lie in beds so deep, that even a small earthquake shall not reach so far downwards, as to affect them; tho' a more violent shock may. And hence we may account for the plague's raging in some parts of *Africa*, once in thirty, or once in a hundred years; since there may be periodical paroxysms, or grand and vehement commotions, in subterranean parts, tho' not yet observed in them. A late judicious *French* historian records, that a very pernicious disease, of the nature of a cholick, reigned in *France* every tenth year, for seventy years together.

Mexeray relates, 'That the great plague which happened in *France* in the year 1346, and which was so contagious, that scarce a village, or even an house, escaped uninfected; began, two years before, in the kingdom of *Cathay*, by a vapour most horribly fetid, and breaking out of the earth, like a kind of subterranean fire; which consumed and devoured above two hundred leagues of that country, even to the very trees and stones; and infected the air in a wonderful manner.' He adds, 'that from *Cathay*, it passed into *Asia* and *Greece*, thence into *Africa*, and afterwards into *Europe*, which it ransacked throughout. *Hist. de France*.

And not only plagues, but most new, contagious, and epidemical diseases, Mr. *Boyle* takes to arise from subterraneous causes. He instances a great cold, which, in one day or two, invaded multitudes in the same city, with violent and fatal symptoms; when yet, he could see no room to judge, that the bare coldness of the air could so suddenly produce a disease so epidemical and hurtful; and it ap-

peared more probable, that the cause came from under ground, because it began with a very troublesome fog.

(e) Peculiar kinds of venomous exhalations, 'tis probable, may sometimes be emitted; especially after earthquakes; and thus occasion mortal diseases in animals of one kind, and not of another; and in this or that place, and not elsewhere. *Fernelius* gives us an account of a plague or murrain in 1514, which invaded none but cats. *Dionysius Halicarnassensis* mentions a plague which attacked none but maids: and that which raged in the time of *Gentilis*, killed scarce any women, and very few but lusty men. *Bitarus* mentions another great plague which assaulted none but the younger sort; and we have instances of the same kind of a later standing. *Cardan* speaks of a plague at *Basil* with which the *Switzers*, and not the *Italians*, *Germani*, or *French*, were infected: and *Joh. Utenhovius* takes notice of a cruel plague at *Copenhagen*; which tho' it raged among the *Dansi*, spared the *Germani*, *Dutch*, and *English*, who went with all freedom, and without the least danger to the houses of the infected.

(f) Eighteen years ago, a terrible noise began at the port of *Santorini*; reaching even to *Chio*, distant therefrom above two hundred miles; which was supposed to proceed from the *Venetians* fighting with the *Turks*: but at length it was found to be caused by a fire underneath the port above mentioned, which there cast up, from the bottom of the sea, quantities of pumice-stones, with a force and report as great as if they had been severally discharged from a cannon. The air of *Santorini* was by this means so infected, that abundance of people were killed, and many

tions from rains, &c. produce such changes in the atmosphere, as entirely to change its nature in the parts adjacent, by means of the moist vapours and exhalations, arising from putrefied bodies. Winds also, which convey the air with its contents from one place to another, thus contribute to change the matter of the air; whence again a great diversity must arise from this cause in chemical operations. The influences of the heavenly bodies, according to the different aspects of the sun, and moon; particularly, their accessions, recesses, perpendicularity, obliquity, conjunctions, oppositions, &c. may occasion wonderful changes in the air, by the heat, cold, attraction, repulsion, vapours, and exhalations they produce; to all which we may well add the changes, occasioned by the variations of the seasons of the year (g). And hence chemists have observed different effects from the same degree of heat in the spring, and the autumn; and prefer the vernal rain to the autumnal, as containing very different particles; on account of the earth's being open in the spring, after it was bound up by the frost of the preceding winter; and more exhausted in the autumn, on account of the preceding summer.

A particular
virtue in the
air.

70. Before we leave the consideration of the different properties, and different substances in the air, we should shew a particular regard to that whereby the life of animals and vegetables is supported; and tho' this cannot be understood from any other property of the air, yet it may be discovered by diligent search. Who will undertake to shew, that this latent virtue is attracted by animals and vegetables from the air, and consumed by them, and that death necessarily follows upon its consumption? Mr. Boyle indeed has shewn, that a small bird, but into a large receiver full of common cool air, and closely stopped up, grows sick in a quarter of an hour, and vomits, and in three quarters dies: fishes in a close vessel of water, unrefreshed by the air, die soon; so they do likewise in lakes, that are froze over; so they do also in water, from whence the air is extracted: flames and burning coals are soon extinguished in a close air; the eggs of insects, shut up close in glasses, do not produce young ones, tho' kept warm; the seeds of plants, tho' first properly steeped, then sown in rich earth, and kept in a proper degree of warmth,

* lost their sight thereby; though they recovered it in a few days afterwards. This infection spread it self as far as the preceding noise had reached; for even at *Cbio* and *Smyrna*, all the coin was changed red, both that in the pocket and that locked up in chests; and the same happened to the silver chalices in the churches. The infection, however, vanished in a few days time, and the silver recovered its native colour. *Voyage de Levant.*

In the year 1660, in the kingdom of *Naples*, after an eruption of *Vesuvius*, strange crosses appeared on linen that had lain open to the air. They were extremely numerous in several parts of the kingdom of *Naples*; and the jesuit, who sent the relation to *Kircher*, says, that he himself found thirty in one altar-cloth; fifteen upon the shift sleeve of a woman; and

eight in a boy's band. Their colour and magnitude were also very unequal, and their figure different; they would not wash out with simple water, but required soap. These were found, not only upon linen garments exposed to the air, but upon some of those that were kept in locked chests.

(g) * Stains caused by vegetable juices, are observed to be best taken out of linen at that time, when the several plants that afford them are in their prime. This one lady has experienced in new linen stained by the juice of quinces; and another in some discoloured by the juice of hops, which she thinks makes the worst of stains; but having tried in vain to fetch this out, she locked up the linen in a chest, till the season of hops came on, and then the spots vanished of themselves. *Boyle, Hist. of Air.*

warmth, yet do not grow, or give any signs of life, if the air be kept from them. On the other hand, when blood is taken from a vein, the surface contiguous to the air, appears red, but where the air does not touch it, black, like the liquor of the scuttle-fish; but as soon as the black surface comes in contact with the air, this also grows red: now all these particulars manifest, that there is a hidden virtue in the air, which cannot be understood by any of the properties, hitherto explained. *Sendivogius* has plainly said, that the food of life lies concealed in the air; other chemists have asserted the same; but what this food is, how it acts, and what are its effects, lie still concealed; possibly it may be its elastic part (*b*). We know that the air is full of water; *i. e.* a ponderous, solid, incompressible body; this water abounds so copiously in the air, as sensibly to wet salt of tartar, when a small quantity is contained in a close glass: but besides water, almost all bodies are contained in the air, which at least must weigh as much as the water; and as these corpuscles are supposed liquid, they are scarce compressible; and if all the corpuscles, that we know have weight, were to be exactly separated from a portion of air, a very small proportion would remain behind for its elastic part: and if I was to form a conjecture from all the experiments I have made, I should go near to say, it was none at all. For, if we suppose, that in a cubic foot of air, only the 850th part of the whole space is possessed by unelastic vapours and exhalations, together with the dusty corpuscles floating

H h h 2 therein;

(*b*) We are extremely apt to be too precipitate in our conclusions: after having learnt a few of the properties of a body, we think we have got all, and impose it on our selves to account for all the phenomena and effects thereof, how various soever, from what we do know. Hence innumerable crude, constrained solutions. No body appears to have been more on his guard, in this respect, than *Mr. Boyle*: he saw abundance of effects from air, which did not appear to have any dependance on the known mechanical properties thereof; and on this view composed that excellent piece of *Suspensions about some hidden qualities of the Air*. 'The difficulty, says he, we find in keeping flame and fire alive, tho' but for a little time, without air, renders it suspicious, that there may be dispersed thro' the atmosphere, some odd substance, either of a solar, astral, or subterraneous nature; on account whereof, the air is so necessary to the subsistence of flame. And this necessity I have found to be more considerable, and less dependent upon the manifest attributes of the air, than is usually observed; for by trials purposely made, it has appeared that a small flame of a lamp, tho' fed perhaps with a subtle thin oil, would, in a large receiver, expire for want of air, in a far less time than one would believe. And it will not much lessen the difficulty to alledge, that either the gross fuliginous smoke in a large

vessel, stifled the flame; or that the pressure of the air is requisite to impel up the aliment into the wicks: for to obviate these objections, it may be observed, that the experiment holds of spirit of wine, which, in the open air, will burn quite away, without any sensible smoke; and this without any wick at all.

Again,—'It seems surprizing what should be in the air, which enabling it to keep flame alive, does yet, by being consumed or removed, so suddenly render the air unfit to preserve flame. It should seem, by the sudden wasting or spoiling of this fine substance, whatever it be, that the bulk of it is but very small, in proportion to the air it impregnates with its virtue; for after the extinction of the flame, the air in the receiver was not visibly altered, and, for aught I could perceive by several ways of judging, the air retained either all, or the greatest part of its elasticity, which I take to be its most genuine and distinguishing property. This undestroyed springyness of the air, with the necessity of fresh air to the life of hot animals, suggests a great suspicion of some vital substance, if I may so call it, diffused thro' the air, whether it be a volatile nitre, or rather some anonymous substance, sidereal or subterranean; tho' not improbably of kin to that, which seems so necessary to the maintenance of other flame.' *Ibid.*

therein; then, the remaining unelastic air would have no weight at all; and hence it would happen, that air could never be compressed into a less space than an 850th part, tho' Sir *Isaac Newton's* law were to hold true in this elastic part; viz. that the elements of bodies resist one another the stronger, the more they are compressed: for hence also it would appear, that this elastic part could not be farther compressed, after the other parts were reduced to the 850th part of their former space; as now the whole space would be possessed by water, and other incompressible bodies: which exactly agrees with the experiments of Dr. *Halley*, and the *Florentine* academicians; who affirm, that air cannot be compressed into less than an 800th part of its bulk (i); tho' we must not hence infer, that the pure elastic part of the air, if it could be had separate, is not compressible to a much greater degree. Hence, I have often been led to consider, whether God did not originally create fire and pure elastic air, without gravity, and without any direction to a certain point, but equally distributed them thro' the whole universe, and all its systems; so as that fire should always act upon air, to keep it moving, even in the utmost degree of cold: for, if at the top of the atmosphere, the degree of heat be less, the air will there be less compressed in the same proportion, as having less weight upon it, and consequently be always so rare, as to be kept in a tremulous motion by less fire. But here it may be asked, if the air, with regard to its elasticity, be without gravity, why is it not rarer near the earth's surface? I answer, that the composing particles of the air cannot easily extricate themselves, as being here so intangled and mixed together; and therefore must here below be compressed by others above. Before I conclude this history of the air, I shall add a few experiments after M. *Mariotte*, who has nobly prosecuted the subject, by way of confirmation to this doctrine of the elasticity of the air.

EXPERIMENT I.

Elastic air
adheres to so-
lids.

71. Take a clean polished plate of silver, and put it into a glass of fair water; bubbles of air will presently appear, and stick to the surface of the plate, thence rise thro' the water and burst at the top: and as this is constantly the case, it shews, that common air first adheres, in invisible particles, to the surface of solid metals, so as to descend with them thro' the water; whilst it adheres to these metals, after the manner of a tenacious substance, without quitting its hold, till forced away by the weight of the water: when, therefore, this plate of silver is moved thro' the air, doubtless, the contiguous air sticks to its surface, till struck from thence, either by heat or rapid motion, when quitting its hold, it is succeeded by fresh air. This property of elastic air should be duly regarded in chemistry; for, as air only adheres to the surfaces of bodies, without entering their substance, 'tis plain, that bodies minutely divided in the air, and thence consequently greatly increased in their surface, must, upon distillation, give out more air into the receiver, than when they are distilled entire. Hence, therefore, the air, produced in dissolving

(i) *Hist. Acad. Royal. An. 1703. p. 7.*

dissolving fine grains of silver, with spirit of nitre, does not proceed from the spirit alone, nor the metal alone, but partly also from the air adhering to the surfaces. But if a solid polished plate of gold, or silver, be so attractive of air, other bodies, doubtless, may be much more attractive thereof. All bodies therefore, when put into water, carry down air along with them; and the more so, as they are rough and unequal, or have larger surfaces; and especially, if at the same time they are light, porous, spongy, and come to be dissolved into their finest particles by the water. And this is the first way of demonstrating, that elastic air adheres to solid bodies.

EXPERIMENT II.

72. Take a large, clean, cylindrical glass; almost fill it with clear water; *And to fluids,* put it under the receiver of an air-pump, and exhaust the air; at first, no *See plate 7th,* change will be perceived in the water, but after a considerable quantity of *fig. 2.* the air is extracted, numerous air-bubbles will arise, and fly very quick, and large, up to the surface of the water: these bubbles, so far as we can observe, proceed from the inner surface of the sides and bottom of the glass; so that a hasty person would infer from this single experiment, that all the air, thus extricated from the water, lay concealed between the concave surface of the glass, and the convex surface of the water: but the contrary will hereafter be shewn by other experiments. In the mean time, we may fairly conclude, that the air here adheres to the surface of the glass and the water, with the same tenacity as in the preceding experiment.

EXPERIMENT III.

73. Air it self also superficially adheres to other air with a remarkable tenacity, tho' its particles may seem to fly from one another. *And to itself.* Take a large round glass, with a long cylindrical stem, whose diameter is about four geometrical lines; fill it with water, invert it, and not a drop of water will fall out, nor a bubble of air get in; which shews that the small particles of air do not easily recede from each other, but adhere with a certain tenacity: for, if the light, elastic particles of the air were as easily separated from each other, as the parts of alcohol, the elastic particles of the air would here pass thro' the water, and rise to the top of it; whilst the water would in the same proportion flow out of the glass, as we have formerly shewn. That the cause is owing to the tenacity of the parts of air, we prove by the following experiments. Fill the same glass with a strong lixivium of salt of tartar, and invert it into another glass of distilled oil of turpentine; thus you will see the tenaceous parts of the distilled oil ascend much slower thro' the ponderous lixivium, than water or alcohol. It may indeed be objected, that this does not proceed from the tenacity of the oil, but from its property of resisting water; and that air may have the same property: but we are to consider, that air also ascends slowly, whether the glass be filled with water, alcohol, brine, any lixivium, or even quicksilver itself. Whence, I conjecture, that the tenacity of the elastic part of the air is here

here greater than in other fluids; and consequently, that being once united, they are more difficultly separable, or divisible into their lesser particles; whence they mix more difficultly with liquors than any other known fluids. Indeed all the philosophers, whom I have hitherto consulted, are of a different opinion, and suppose, that air immediately enters all the liquors it touches; but a careful observation has made me judge differently: for let this same glass be two thirds filled with liquor, and the remaining third contain nothing but air, and the top be exactly closed with a glass stopper; if you shake the vessel ever so long, the air will never be perfectly mixed with the liquor, but only large bubbles be produced in the water, where the particles of air mutually lay hold of one another, and roll about together; whilst the agitated parts of the water form a little sphere on the upper part, which confines the air: and from a number of such bubbles there arises a white froth, consisting of air and water, and returning back into each respectively: these bubbles are about 3 lines in diameter. To confirm this paradox, I shall add the following experiment: Take a glass phial, full of common air, with its mouth not 4 lines in diameter; plunge it perpendicularly under water, with its open mouth upwards; the water will now press upon the surface of the air in the glass, and not enter, but be sustained by the air: whence, we see that water, tho' 850 times heavier than air, cannot thus divide the parts of air, so as to insinuate between them. But it is here remarkable, that if the glass full of water, has a mouth 5 inches in diameter, and be inverted with its mouth downwards, a large bubble of air enters the neck, and passes entire, upwards thro' the water: at the same time we may observe, that the surface of these bubbles, which thus ascend, are both ways convex, whilst the concave surface of the water, thro' which they pass, accommodates it self to the air. This appears more plain, whilst the stem of the phial is held parallel to the horizon under the water. The same holds also of slender glass tubes, full of air and open at both ends; for, if these are placed perpendicularly in water, the water ascends so as to form a concave surface in the upper part; whilst the air in its lower surface is convex. All which seems to shew, that the elastic part of the air has a considerable, determinate degree of tenacity; tho' some are pleased to explain these phaenomena by the attraction which is found between water and glass.

See plate 7th,
fig. 3, and 4.

Fig. 5:

EXPERIMENT IV.

Elastic air in water.
Plate 8. fig. 3.
74. Take three conical glasses, A, B, C, with flat bottoms, and narrowing upwards, but open at top: In the first put cold water of the temperature of the air, suppose 44 degrees; in the next, warm water, 91 degrees; and in the third, hot water, of 150 degrees: put these glasses under the receiver of an air-pump, and exhaust the air. As soon, as a little air is drawn out, numerous bubbles will be generated in the hot water of the glass C, and appear about the bottom and sides of the glass; whence they rise, grow large, and burst at the surface, as if the water were in a boiling state, tho' it be 70 degrees below that state; but in the glass B, where the heat was only 91 degrees,

degrees, no such motion of the particles will yet appear; but after more air is extracted, the water in this glass will also begin to generate great bubbles; the water in the glass C, still remaining quiet: and after a great deal more air is extracted, the water in the glass C, will also begin to bubble, and continue to do this a long while, if the receiver be well emptied. Whence we see, that pure elastic air may lie concealed in water, without manifesting any sign of itself in the cold, and under the pressure of the atmosphere; and tho' water thus conceals compressible air within it, yet can it by no means be itself compressed, as we learn by the experiments of the academy *del Cimento*. Whence it appears, that air, lodged in water, must be seated in the vacuities betwixt the component particles of the water: and it could not possess these spaces without being able to interpose itself between the particles of water, where they are in mutual contact; otherwise the water, containing this air, must be compressible. In these pores, therefore, between the last particles of the water, those of the air may rest: and hence it is probable, that the air, thus situated, and remaining there insensibly in the cold, requires, that the water be compressed by the weight of the atmosphere, to keep it there; and that when the parts of the water are less compressed, than these concealed particles of air rise up thro' the incumbent water, quit the pores where they lay concealed, and leave them empty of air. We also know, that heat disposes the intercepted air to quit the water; so that the hotter water grows, the more easily air slips from it; whence the largest part of it escapes upon long boiling. Lastly, we learn by experiments, that wine, beer, and brandy, part with their air-bubbles the quicker in the air-pump, the more inflammable spirit they contained. All which is more fully illustrated by the following experiment.

75. Take a cylindrical glass vessel AB, with a flat bottom, and half fill it with fair water; have ready also a spherical glass phial CD, with a long stem D; fill this with water, and fix the finger upon the mouth D, so as to touch the water in the neck; then plunge the neck under water in the glass AB, so that no air, nor any thing but water, may remain in the phial D. Set both vessels, in this posture, under the receiver of an air-pump; and when the air is nearly exhausted, the water in the cavity of the phial C, will fall by its own weight, down the neck D, into the glass AB; the surface of the water in the glass AB, being no longer pressed by the weight of the atmosphere: and thus, a *Torricellian vacuum* will be made in the cavity C, above the descending water; whence the water there will not be pressed upon. And hence, the air making numerous bubbles in the water contained in this cavity, and all rising thro' the water in the neck, and in the phial, to the *vacuum* above, and bursting there, all the air will thus collect from the water contained in the vessel CD. Let the whole apparatus remain in this situation, till no more bubbles are formed, or rise to the upper part of the phial; then suffer the air to enter into the receiver; which, immediately pressing the surface of the water in the glass AB, will force the water thro' the mouth D, into the cavity C: but when all the external air is admitted into the receiver, the water now will not fill the cavity as before; but an air-bubble, consisting of elastic air, remain in the upper part, being what was discharged from that water in the preceding

ing operation, in the form of bubbles; which did not rise, till a large part of the air was drawn out of the receiver. But these bubbles never arise from water, till so much air is extracted, as, we find by the gage, exceeds a tenth part of the weight of the atmosphere; and as the greatest variation of the atmosphere with us, never exceeds a tenth, there is no danger, that water should, on this account, naturally part with its air: nay, even water heated to 90 degrees, and freed from a tenth of the weight of the atmosphere by the pump, does not discharge its air in bubbles: whence the air contained in the juices of the body, is never separated from them, even in the lightest state of the atmosphere in our climate. It may here be asked, how it can be proved, that the large air-bubble produced at the top of the phial, is true elastic air? The proof consists in this, that it expands, and contracts, in proportion to the compressing weight, or heat and cold applied; which are the true characteristicks of air.

Air in water. 76. It may also be questioned, whether the air, thus produced, is really separated from the water; or does not rather proceed from the space between that and the glass: but the following arguments will shew it to proceed from the water. And first, we must observe, that a very different quantity of air is thus produced from equal quantities of different fluids; thus quicksilver, water, wine, brandy, beer, alcohol, rosy wine, fermenting wine, half-fermented beer, and must, or stum, afford such different quantities of air *in vacuo*, as make it plain, that this air does not proceed from the surface of the containing glass, but from the innermost pores of the liquor. Add, that some fluids afford little or no air under this treatment: thus oil of tartar *per deliquium*, tho' made in the air, scarce affords any by this experiment; no more does the volatile spirit of sal-ammoniac, if made extremely strong. Again, we shall hereafter shew, that all the air, thus generated, will be reformed into the water from whence it was discharged; and that the water afterwards can by no art be made to take in more air: which plainly shews, that much the greatest part of the air in question proceeds from the water.

And other fluids.

77. It remains only to observe, that this air has been obtained, by the same experiment, from water, vinegar, distilled vinegar, urine, spirit of urine, oil, water and oil together, expressed oil, milk, blood, serum, eggs, the white of egg, and from quicksilver: but if the same experiment be made upon water, that has constantly been kept boiling for an hour, it scarce affords any air at all.

EXPERIMENT V.

Air re absorbed by water.

78. Water being well purged from all the elastic air it contains, then cool'd to the temperature of the atmosphere, and exposed to the common air; elastic air will then spontaneously and quickly enter, and seat itself in the pores thereof: and this it will constantly do to a certain degree. This remarkable property between water and the elastic air, may be thus exhibited to the eye. Let the apparatus be the same as in the second part of the last experiment, where

whence the elastic air was collected at the top of the phial; then if that bubble of air be compressed in the condenser, yet the air will not thereby be mixed with the water; but, on the other hand, if the whole apparatus be exposed to the external air, the bubble will begin to diminish; and, at length, will totally vanish, and the whole cavity appear filled with water alone: and this constantly happens, so as that, at first, a large part of the collected air soon enters into the water; whereas, the last particles enter very slowly. Hence, therefore, water will always perfectly re-absorb the air that was artificially discharged from it.

79. It is remarkable, that if this experiment be made with water, already saturated with its natural dose of air, it can receive no more; for if, in the same apparatus, the air was not to be extracted, but the air-bubble to remain at the top of the water, and the vessels were to remain thus for a year, this air-bubble would not enter into the water, but still remain on the top; and this, tho' the glasses were to be shook: indeed, the air-bubble would be thus divided into less bubbles; but, with my utmost endeavour, I could never mix them, so as to render them invisible in the water; yet I have tried to do it by compressing, heating, cooling, shaking, and by rest: nor could I find it possible to mix more air with the water, than what it naturally contains.

Air does not enter water already saturated.

80. In prosecuting these experiments, I could not help remarking, how small a part of the surface of the water was touched by the air-bubble at the top of the glass; and how from such a small surface it insinuated itself thro' the whole large body of water, from whence it was before collected: and as it was thus again equally distributed thro' all the pores of the water, there must of course be some attractive power in all the points of the water, with respect to the air, which thus enters it spontaneously, and without shaking: and so much for the first method of separating elastic air from water, by removing the incumbent weight.

Air diffuses itself through the whole bulk of water.

EXPERIMENT VI.

81. It is a curious experiment to separate water by fire, and to collect and manifest it; which may be thus done. Take a large, wide vessel, A B, capable of bearing the fire, and having a flat bottom; fill it with common water; into this put a funnel, whose widest part may nearly spread over the whole bottom of the vessel; and let its narrow part C D be plunged under the water; then take a glass phial E F, whose stem E is large enough to receive the end of the funnel C D; fill this phial to the top with water, and closing the orifice with the finger, invert it into the water of the vessel A B, without letting any air come into the phial, and thus invert the neck upon the end of the shank of the funnel; then place the vessel A B, with this apparatus, over the fire, that they may all grow gradually warm together; and at length the water in the vessel A B be brought to boil briskly: by which means, the water under the funnel will determine the air of the boiling water, now rising in bubbles, to pass thro' the funnel into the neck of the phial, and thence into

Air separated by boiling.
Plate 8. fig. 3.

the belly thereof, where it will be collected together at the top F; when, after a time, a certain quantity of true elastic air will be found separated from the water; nor can more than a certain quantity be thus collected, tho' the boiling were ever so long continued. It is here remarkable, that after the water has discharged all its air in bubbles, at the top of F, yet in the farther boiling, other large bubbles suddenly arise with great impetuosity, so as to shake the glasses, when they discharge, and yet produce no air upon breaking. These bubbles, therefore, do not arise from air, but from fire acting within the water, and therefore these always continue how long soever the water be kept boiling; whereas the air-bubbles soon cease to rise. These two sorts of bubbles differ in their size and manner of breaking; the fire-bubbles being large, and breaking with a crack; but the air-bubbles small, and bursting gently. If, in this state, whilst the air remains collected at F, the whole apparatus be left in the cold, the air will return back into its water. I once boiled rain-water, in the strongest manner, for two hours, then placed it under the receiver, with the apparatus of the preceding fourth experiment; when extracting the air as carefully as possible, no air was at first found at the top of the phial C; but after having kept this water *in vacuo* for some days, a considerable quantity of air was produced: whence, I have some doubt, whether water be transmutable into air, upon being detained so long *in vacuo*; or, whether air may so closely adhere to water as not to be discharged by boiling, tho' it may be thence slowly separated by time, *in vacuo*.

EXPERIMENT VII.

*Air separated
from water
by freezing.*

82. Put rain-water into a conical glass that widens upwards; expose it to a hard frost, and the parts of the water will be contracted by the cold, tho' no force of weights was before able to compress it; but whilst the frozen parts are brought closer together, and of course the spaces between them diminished, the particles of air, lodged therein, are squeezed from their places, and united together; whereupon they seem to acquire an elasticity, which they did not appear to have when single. Thus, therefore, these air-bubbles begin to manifest themselves, grow large and more numerous; and, at length, being very great, they rise upwards; when being resisted by the ice, they move thro' it by their elasticity, swell the ice every way, and burst the containing vessel; and the harder or longer it freezes, the larger, more numerous, and more forcible these elastic air-bubbles become: whence ice appears to enlarge its dimensions by cold, tho' in reality it lessens them; only, the air-bubbles, thus produced, possessing large spaces in the ice, thus increase the bulk of the whole; whence if the frost be sharp and long continued, all the air, that was dispersed thro' the water, is separated from the pores of the ice, and collected into bubbles: which shews us another way of separating air from water.

EXPERIMENT VIII.

83. As oil of tartar *per deliquium* is made by salt of tartar attracting *Air separated from water by alkali.* the water diffused in the air, and easily turns to froth; this ponderous liquor has been supposed to be full of elastic air: but I have found, by all kinds of experiments, that it manifests no signs of air in the exhausted receiver, by boiling over the fire, or by freezing; whence we conclude, that fixed alkaline salt, upon its insinuating into water, discharges the particles of air, possesses their places, and thus constitutes the heaviest fluid, next to quicksilver; unless we should rather say, that it fixes the air without expelling it.

EXPERIMENT IX.

84. I directly put the warm, morning urine of a healthy person under the receiver of the air-pump, and immediately extracted the air, as much as *warm fluids from the animals.* possible, without perceiving any signs of air-bubbles for a long while, tho' the urine was ninety degrees hot, and the air pumped out to twenty-six inches; but working the gage to twenty-seven inches, bubbles began to appear; and proceeding still farther, this urine on a sudden began to boil in the *vacuum*, more violently than it does over a strong fire. It is hard to say from whence this sudden and violent motion of the urine should proceed; whether it be from the air, or from the fire, contained therein, or from both. I made many similar experiments upon different animal fluids, and strong brines of sea-salt, nitre, sal-ammoniac, the volatile salt of sal-ammoniac and quicksilver, which might be worth repeating, but are tedious to relate.

COROLLARY I.

85. It follows from our experiments, that tho' the particles of elastic air adhere together with some degree of tenacity, yet it can resolve itself into its minutest particles, and spontaneously insinuate into the pores of liquids, exhausted of their air; and this equally thro' their whole mass: consequently, the air is attracted into these liquors, and into these pores.

COROLLARY II.

86. The air, thus attracted into the pores of liquors, is in the action dissolved into its minutest particles; as being distributed thro' their whole masses.

COROLLARY III.

87. But the quantity of air, thus absorbed by liquors, and diffused thro' them, is very small, and takes up very little space therein.

The Theory of CHEMISTRY.

COROLLARY IV.

89. These liquors, of what sort soever, when once saturated with this small quantity of air absorbed, can by no means be made to receive any more; and if attempted by motion, compression, &c. they reject, and repel it in the form of froth, or bubbles.

COROLLARY V.

90. Liquors, and especially of the aqueous kind, when once saturated with any sort of salt, will not afterwards absorb air.

COROLLARY VI.

91. A single particle of air, thus lodged in a pore between the particles of a liquor, does not seem to be air, as we commonly know it by its physical marks, as not appearing to be elastic in this state; at least there is no experiment to prove it. Again, such a single particle is not easily dilatable by heat; a considerable degree whereof is required to remove it from its place: hence, therefore, as a single magnet has no magnetical effects, unless another be near it, and cannot in this respect be called a magnet; so a particle of air, existing by itself, cannot in this respect be called air: they also agree in this, that they both act only within their respective spheres of attraction.

COROLLARY VII.

92. But when, by any cause, two such single particles of air are dislodged from their pores in water, and come so close as to touch, they seem mutually to repel each other, and thus form a small bubble.

COROLLARY VIII.

And as this smallest of bubbles, consisting only of two particles, possesses all the above-mentioned properties of elastic air; whilst this bubble rises from the bottom to the top of the liquor, it passes thro' the pores thereof, where meeting with similar single particles of air, it increases into a larger bubble, and is the less pressed the higher it ascends.

COROLLARY IX.

93. Hence also, salts appear to attract this elastic air, less than liquors, especially of the aqueous kind.

COROLLARY X.

94. Hence, in all the known liquors, there seems to be only one determined proportion of air contained; and this always a very small one, tho' very different in different fluids.

COROL-

COROLLARY XI.

95. Hence it may be questioned whether the air, which produces the effect of fermentation in vegetable liquors, be only that which lodges separately in their smallest pores; or, whether this be not rather assisted by that truly elastic air contained in the air-vessels of vegetables; or again, by the external air, usually intermixed with fermenting subjects.

COROLLARY XII.

96. The elastic air contained in the juices of animals, and here divided into its minutest particles, does not seem to be the cause of putrefaction; as animal subjects scarce putrefy without the admission of the external air, and in the open air putrefy quickly.

EXPERIMENT X.

97. The elastic, elementary air, which, when divided into its minutest particles, is thus dispersed thro' the body of water, is there so small in bulk, *How much air in water.* as to escape the senses; but when separated from the water and collected together, it takes up more space than all the water from whence it was discharged: this appears to the eye by the following experiment. Let there *See plate 8.* be a parallelopiped vessel A B, of copper, with a little cavity C, made in *fig. 4.* its bottom, capable of holding a drop or two of water; let there be also a small conical glass D, open at the bottom, fill the vessel A B, with pure expressed oil, so that the erect conical glass D, placed at the bottom of the vessel A B, may be covered therewith; then lay this conical glass, horizontally on its side, as in F; so as that no air may remain in it, but its whole cavity be perfectly filled with oil; now place the whole apparatus over the fire, that the oil in the vessel and in the conical glass may boil, till the oil ceases to crackle; whereby all the air and water, if there was any, will be discharged from the oil. After this, let all cool: then by means of a small glass-pipe, let a single drop of water be introduced, thro' the oil, into the little cavity C, which water will remain there, under the oil, by its own weight; then let the little glass D, remaining continually under the oil, to prevent any air from entering, be placed erect over the little cavity C, so as to cover the drop of water centrally; in which case, the little glass will be full of oil, without the least admixture of air or water. Now place the vessel with its whole apparatus over a furnace, so as that the flame of a lighted candle may commodiously be applied under the cavity, where the drop of water is lodged; and this so slowly and carefully, as that the drop of water may grow hot by degrees: this drop of water, now coming to boil, will cause a considerable noise under the oil, and the little glass; and discharging its air towards the top of the little glass, 'twill there possess a considerable space so long as the heat continues, and proportionably force out the oil from the conical glass. The motion will here sometimes be so strong, whilst the drop

drop of water is boiling, as to rise up the glass. When by this means, all the air is discharged from the drop of water, let all cool; then the air in the little glass, being cooled, will be pressed into a bubble at the top, and appear greater than the drop of water from whence it was discharged. Lastly, let the whole apparatus be placed upon the air-pump, and the air be extracted; when the air-bubble at the top of the little glass will expand itself, and proportionably repel the oil, and manifest its elasticity, upon taking off the pressure of the atmosphere; as it did before, upon increasing the heat: but when the external air is admitted into the receiver, the bubble returns to its former size: whence, there is no doubt to be made, that the air here generated is true elastic air.

*Air in water
is not air.*

98. Hence, we learn, that the air which is dispersed in water, is not there such a fluid body as it makes after being separated from the water then collected, and its elastic parts united into one bubble; and that air, concealed in liquors, has not the same physical properties, as when united out of liquors; and consequently, cannot produce the same effects in both cases: it is, therefore, unsatisfactory reasoning, that because air may be produced from liquors, therefore it must act as air in those liquors: and in this respect most authors have been mistaken, even the acute; for instance, *Borelli*, in his treatise *De motu animalium*; where he mentions the vital oscillation of elastic air in the blood: which may caution us not to reason, so as to be contracted by experiments.

*Elasticity of
air from
union.*

99. We farther learn from our experiment, that the elastic particles of air, whilst they exist separate, possess less space than when they are united; whence, the power of expanding themselves arises from their coming together; and therefore, possibly they may repel each other, when they are closest: this was *Sir Isaac Newton's* opinion; and the progress daily made in experimental philosophy, renders it more and more probable.

*The particles
of air very
penetrating.*

100. We learn from the preceding doctrine of the nature of air, that, when resolved into its primary single particles, it may pass thro' very small pores; for, water containing its own proportion of such divided air, they both naturally pass together; as we see by experiments, made upon animal, vegetable and mineral substances; since the water, obtained from them, always affords elastic air; whence, such air cannot be excluded from those places, where the liquors that carry it can enter; and therefore, in this respect, elastic air must have a large spread.

*Its entire
body not very
penetrating.*

101. But air in its entire body will not pass thro' those pores which it easily enters when mixed with liquors; nor can the least air-bubble pass where liquor and air together may gain entrance; even the primary particles of air can scarce any way pass thro' liquors already saturated with air; tho' they do it easily where the liquors have been deprived of air: whence, perhaps, we may safely conclude, that in general, the air mixed with liquors, does not act in them by any power usually attributed to common air: but when, by the causes above-enumerated, it begins to be separated from the liquors wherein it was contained, it then puts on the nature of true air, and all its properties. Air, therefore, is naturally present in chyle, milk, blood, serum, saliva, bile, the pancreatic juice, urine, &c. but so dispersed, as not

to act as air: and since we have seen, by the above experiments, that air concealed in liquors cannot be discharged from them by a heat of ninety-two degrees, which is the highest that healthy blood will bear; hence, it follows, that the air intermixed with the animal fluids, cannot naturally separate in a healthy body, or collect into air-bubbles, or have the effects of true air: but if this at any time happens, it must prove instantly fatal, as is known from the history of anatomical injections; where the experiment has been frequently repeated, and always with the same event. Thus, *Ruyfch* found air had inflated the heart of a man he dissected; and *Hippocrates* mentions wind in the blood-vessels as mortal (*k*).

102. We now proceed to a few other experiments, whereby elastic air is extricated from bodies wherein it before lay concealed; and for this purpose I had an air-pump so contrived, that I could easily mix bodies *in vacuo*; which *vacuum* was so perfect, that the mercury in the gage stood at 28 inches and $\frac{1}{2}$. In a vessel, placed under this receiver, I put a dram and half of whole crabs-eyes; and pouring an ounce and half of warm distilled vinegar upon them *in vacuo*, a violent ebullition presently arose in the glass, occasioning the mercury in the gage to descend twelve inches in half an hour's time: the receiver, here employed, contained seven pints of water; and the natural heat at this time was fifty-two degrees by the thermometer; whence the density of the air produced in the receiver, was to that of the atmosphere, nearly as 24 to 57. *Air from pur-vinegar and crabs eyes.*

103. 'Tis remarkable, in this experiment, (1.) that the ebullition is much stronger *in vacuo* than in the open air; which, therefore, is not here necessary to press the vinegar into the crabs-eyes. (2.) That so much elastic air is here generated, as to possess the space of eighty cubic inches, and by its elasticity resist the pressure of the whole atmosphere. (3.) That this quantity of air may lie concealed in these bodies, so as to give no signs of itself, till the ebullition sets it free. (4.) 'Tis hence probable, that the elastic air here generated, does not weigh like common air full of vapours. (5.) Hence, it appears, what would be the consequence if an absorbent, like crabs-eyes, an acid, like distilled vinegar, and a *vacuum* were to be found in the vessels of the human body: we may justly suspect that no such ebullition can happen in the body; as so much air would be thence produced, a little whereof, being admitted into the veins, is mortal.

104. I put a dram of chalk to two ounces of distilled vinegar *in vacuo*, *From chalk.* and found a much more violent effervescence arise than in the open air; the mercury in the gage fell from 28 $\frac{1}{2}$ to 6.

105. Upon putting oil of tartar *per deliquium* to distilled vinegar *in vacuo*, *From oil of tartar and vinegar.* there arises a very violent and sudden ebullition; and only a moderate one at first, when this is done in the open air: a very large quantity of air is suddenly produced in the former case; and yet 'tis remarkable, that no air can be found in oil of tartar, and that a very little fixed alkali saturates vinegar. Now, as these effervescences are hindered rather than promoted by the open air, they must necessarily proceed from some power in the bodies themselves.

From oil of
tartar, and
oil of vitriol.

106. The following experiment should be made with caution, viz. the mixing of strong oil of vitriol with strong oil of tartar *in vacuo*. M. Homberg has shewn, that eight parts of salt of tartar may be saturated with five of oil of vitriol; which proportion we therefore make choice of: and knowing, that a violent ebullition arises upon mixing these two liquors in the open air, I, first, endeavour to free them from the air they may contain, to lessen as much as possible their expansion *in vacuo*; and afterwards use vessels capable of containing twenty times the quantity I employ. Then setting the vessel, wherein the mixture is to be made, in a glass dish, and the vessels of oil of vitriol and oil of tartar with it, upon the air-pump, I cover them all with a receiver; then exhaust the air as much as possible: during the working of the pump, not the least air-bubble arises from the oil of tartar, but a great many from the oil of vitriol; then leaving them *in vacuo* for fifteen hours, I afterwards mix the oil of vitriol and oil of tartar together; when a most violent effervescence instantly arises, so as to scatter particles of the liquor with great force all about the receiver. In the mean time, the mixture swells to twelve times its bulk. I took only four drams of oil of tartar, and a dram and half of oil of vitriol; and tho' the oil of vitriol seemed perfectly purged of air, and the oil of tartar seems to contain none; yet the air, produced by this effervescence, sunk the gage from twenty-nine inches to twelve and a half: whence it clearly appears that all the elastic air lodged in fluids, cannot be extracted from them by the air-pump; but that the largest part thereof adheres so tenaciously, as not to be set free without this effervescence; so that the air-pump has but a very limited power in this respect: and any one would be deceived, who should expect, that all the air may be extracted from liquors by their remaining for twenty-four hours *in vacuo*.

107. It should seem, from the preceding experiments, that the effervescences, which thus happen between acids and alcalies, owe their origin to the strong reciprocal attraction of the salts; whereby they at a certain distance violently rush into one another, and in the shock expel the particles which lay between them or hindered their coming together, and intimately uniting. From this violent dislodgment of these aerial particles, made in the act of union, the elastic air, here interposing, must be expelled, and uniting with others of the same nature, form bubbles and explosions; so that all the struggle, which happens in effervescence, is not owing to any repugnancy between the salts, but rather to their mutual attraction and coming together. Hence, all conflict totally ceases as soon as the union is completed; but the effervescence is not over so long as any particles of these salts remain separate: hence, we see that even the water itself, wherein the acid and alkaline salts were held dissolved, is struck out, and separated from them; for both the oil of tartar, and oil of vitriol, being liquid before they are mixed, yet after they unite by a strong effervescence, they produce a white, solid salt in the midst of the displaced water; whilst only an aqueous part floats above it, weakly impregnated with some of the dissolved salt.

108. It must indeed be owned, that the salts produced from an acid and an alkali, united by effervescence, still contain a wonderfully elastic air; as

appears

appears from experiments; for, if sea-salt, nitre, or *tartarus vitriolatus*, regenerated from their own acid, and salt of tartar, be mixed with bole, and distilled in an open fire, they plentifully discharge elastic air; and this so forcibly, as to break very capacious, and very strong vessels: which calls to mind the *gas sylvestre* of *Helmont*, and makes one doubt, whether, what is thus generated, and dislodged, be true, elastic air; or whether, when bodies are in a certain manner resolved into their minutest particles, they do not lose their former nature, and change into elastic air; which concret- ing with other particles, constitutes them new solid bodies; or lastly, whether there be not in nature, something like common elastic air, without being air.

109. But to go on with our experiments: put a glass of the strongest spirit of nitre, with the same cautions, into the receiver, and exhaust the air as much as possible; the spirit of nitre will scarce afford any bubbles all the time; tho' the stronger acid spirit, or oil, of vitriol in the foregoing experi- ment, afforded so much. Into this spirit of nitre *in vacuo*, put a grain or two of iron-filings; a violent ebullition will immediately arise, and a gross red fume diffuse itself all over the receiver, with an explosion, so vio- lent as to endanger bursting the glasses: but it is here remarkable, that tho' elastic air be thus generated, yet it is not in such quantity, or capable of sinking the quicksilver in the gage, so low as might be expected from such a violent ebullition and fulmination, attended with gross, red fumes; all which immediately cease upon letting in the external air, whereby the liquor shrinks into very small dimensions; whence, we see that great and violent explosions of bodies may arise, without a proportionable concurrence or production of elastic air.

110. It may here be proper to relate an experiment, that is not rashly to be repeated, but stands described in the *Philosophical Transactions* (1): A glass receiver, six inches wide and eight inches deep, being applied to the air- pump, and the air being drawn out as far as possible, after half a dram of spirit of nitre, contained in one glass, and a dram of the distilled oil of caraway-seed, contained in another, were put under it; then these two li- quors were mixed *in vacuo*, and in an instant, the glass-receiver was forced upwards in the air, and the mixture took fire. Whence it appears, that much air was here generated from a dram and half of the liquors; and by ex- panding itself with a great force, raised up 468 pound weight; and might perhaps have raised more, as it threw off the receiver with great violence: yet the air of both these liquors was before extracted by the air-pump; and this force, or elastic air, was generated in an instant; whilst at the same time, the whole receiver was full of flame: whence, the air was the more expanded by the fire, and acquired the greater force; so as to act both by its elasticity, and its expansion by heat. Hence it is not easy to estimate the de- gree of this force, unless perhaps by using a receiver still larger and larger, till at length the exploding matter could not raise the receiver; which, for this purpose, might be kept from breaking, by a pulley and weight.

111. The last method of producing elastic air is by means of heat or fire, as in fermentation, putrefaction, distillation, or calcination; but here the subject

K k k

Elastic air produced from bodies by fire.

(1) N^o. 213. p. 212.

subject would prove too copious: vegetable juices dilate considerably in fermentation; Mr. Boyle has shewn, that bodies produce much air in putrefaction; Helmont has remarked, that crude tartar, in distillation, will burst very large and strong vessels, if closely luted; so, in the distillation of animal substances, the retort and the receiver are extremely apt to burst; and in the distillation of nitre, salt, vitriol, alum, &c. violent, elastic vapours arise. Indeed, nearly all sorts of bodies, treated by fire, shew, that elastic air makes a considerable part in their composition; at least, that all known bodies do, by the force of fire, separate a fluid, elastic, compressible matter, that contracts with cold and expands with heat, which are the properties of elastic air; tho' this matter, when confined and bound down in bodies, does not produce the effects of air; but when once let loose, it has all the effects of air, and may again enter as an ingredient in the composition of other bodies. Chemistry clearly shews this manner of resolution and combination: and no examples hereof need at present be produced, after what Dr. Hales hath written upon the subject in his vegetable statics. And here I should end my history of air, wherein I have laboured to shew how necessary a knowledge of natural philosophy is to a chemist; and indeed, all those arts, whereby natural philosophy may be improved; as without these, a chemist will every where fall into errors himself, and impose upon others, by assigning false causes for true ones.

Corollaries
with regard
to chemistry.

112. From this inquiry we learn, that all the subjects of chemical operations, and the operations themselves, are exposed to this air we have been considering; and consequently, that they are liable to the accidents thereof; whence, in all the effects produced, a chemist should carefully attend, how far the air may contribute to them: and in this view, it may be proper to repeat all the concurring effects of the air in chemistry. 1. Therefore, it surrounds, touches, restrains, and compresses all chemical subjects, both solid and fluid; insinuates into their pores, and there acts according to its nature. 2. Being determined to these subjects by its gravity, and being divisible by its fluidity, and thus insinuating itself into their pores, and there meeting with particles whereto it is particularly attracted, it unites with them, loses its fluidity and elasticity, and remains united with them, till set free again by effervescence, fermentation, putrefaction, or heat; at the same time, by means of other particles it contains, producing many other effects. 3. It mixes bodies among one another by its weight, and the constant velocity of its motion; thus producing very particular and extraordinary effects; as was well known to the ancient adepts, and particularly to Helmont (m), who has made great use thereof: and the like effects would be in vain expected in a higher, a lighter, or less degree of air; as we see in the mixing of oil of turpentine with salt of tartar, which does not succeed high up in the air. 4. Hence, the action of one body is applied, and determined upon another; for, all things, heavier than air, are pressed upon by it, moved with its motions, and mixed together; so that, if any particles among them receive a particular property by coming in contact with air, such property will be thus excited and made manifest. Hence, many solvents

(m) See Helmont, p 151. §. 45. p. 334. §. 84. &c.

solvents will scarce act at all *in vacuo*, but freely in the open air; as spirit of sal-ammoniac upon copper; and vinegar upon iron and copper; but a most remarkable instance to this purpose is afforded by *Papin's digester*; where the air and water being forcibly pressed and determined to act upon the subjects by heat, presently soften bone, &c. 5. The air, as a whole, gives a kind of perpetual motion to bodies, as by the least change of heat it immediately contracts or expands; and as these changes are perpetual, there is a constant vibratory motion in the air: the like happens also upon the constant variation of its weight; as appears by the diagonal barometer, where the quicksilver rising two inches, the atmosphere rises 23800; so that, since the quicksilver in the barometer never remains at the same precise height, the atmosphere must constantly vary in its weight. And since this air insinuates itself into the pores of bodies, it must here excite a perpetual motion; and hence, perhaps, it is, that all the principal natural effects are produced in the open air. Thus paste does not rise, nor animals easily putrefy, nor fruit soon corrupt *in vacuo*; whence it appears, that without air the parts of animals, vegetables and minerals would remain almost unchanged. 6. The air seems to contain particles proper to dissolve all sorts of bodies; as nearly all sorts of bodies float dissolved in the air, it must needs happen, that one time or other, the properest dissolving particles will be applied to every body, respectively: in which light, the air may be called an universal solvent (*n*). Thus there is no metal, or metallic matter, but sooner or later is prey'd upon, or corroded, either in, or by the air; but it would be endless to mention all the effects of the air upon bodies: in a word, it makes manifest what was obscure; obscures what was manifest: sheathes what was corrosive; un-sheathes what was mild; fixes what was volatile; volatilizes what was fix'd; produces colours, and destroys them, &c. &c. To conclude, it is plain, that the same subject, treated apparently in the same manner, may produce a different effect, if the air be different: whenever, therefore, any chemical process is described, let a particular regard be had to the state of the atmosphere; otherwise it will be impossible to arrive at certainty, or any uniformity, in experiments.

(*n*) See the Note, pag. 406.



Of WATER.

Water hard
to be known.

I. **A**S water is common to be met with, and comes to be used on every occasion, men are apt to imagine they thoroughly understand its nature; but those who have carefully applied themselves to the examination thereof, find it one of the most difficult subjects in all natural philosophy to be acquainted with. A principal cause of this difficulty is the labour required to separate water from other bodies, or other bodies from water; which continually mixes itself with chemical subjects, and especially with the air (*o*), wherein all chemical operations are performed; so that it is scarce any where excluded. Thus the hardest and dryest bone, by distillation affords a spirit, that contains water; so likewise stone and brick, when reduced to powder and distilled, in dry vessels, give out an aqueous moisture, which, as a kind of cement, enters their composition, and sticks their particles together; for brick is made by mixing water with dry powdery clay, then drying and burning the mixture (*p*). That the air abounds with water, we shewed in the preceding chapter; and it may be proved to the sight, by exposing a piece of ice to the air in the heat of summer, when an aqueous vapour will presently appear as collected about

(*o*) It is disputed, whether or no, water be convertible into air. In the vapours daily raised, we find water rarified to a great degree, so as to take place in the atmosphere, and help to compose a considerable part of what we call air; and even to contribute to many of the effects, ascribed to the air: but such vapour-air has not the characters of true, permanent air; being easily reducible into water again. So, in digestions and distillations, the water may be rarified into vapours, yet it is not really changed into air, but only divided by heat, and diffused into very minute parts, which, meeting together, presently return to such water as they constituted before.

Water, rarified into vapour in an æolipile, will, for a while, have an elastic power, like that of air, and be driven out in a stream, much resembling air; but the elastic power of this stream is manifestly owing to nothing else but the heat, that expands and agitates the aqueous particles thereof; and, when that heat is gone, the elasticity and other aerial properties disappear likewise: rapid winds, thus made, seem to be no more than mere water, broke into little parts and put into motion; since by holding a smooth, solid and close body against it, the vapours condensing thereon, will presently cover the body with water,

Tho' no heat intervenes, says Mr. Boyle, perhaps motion alone, if vehement, may suffice

to break water into minute parts, and make them ascend upwards; if they cannot, otherwise, more easily continue their agitation: for, I remember that betwixt Lyons and Geneva, where the Rhone is suddenly straitened by two rocks exceedingly near each other, that rapid stream, dashing with great impetuosity against them, breaks part of its water into such minute corpuscles, and gives it such a motion, that a mist, as it were, may be observed at a considerable distance, arising from the place, and ascending high into the air. Boyle's Phys. Mechan. Exp.

(*p*) 'Tis surprising to observe, how great a share of water goes to make up several bodies, whose forms promise nothing near so much: eels, by distillation, yielded me some oil, spirit, and volatile salt, besides the *caut mortuum*: yet all these were so disproportionate to the phlegm, that they seemed to have been nothing but that coagulated: which likewise strangely abounds in yipers, tho' they are esteemed very hot in operation; and will, in a convenient air, survive, for some days, the loss of their heads and hearts. Human blood itself, as spirituous and elaborate a liquor as it is reputed, so abounds in phlegm, that distilling some of it, on purpose to try the experiment, out of about 7 half ounces, we drew near 6 of phlegm, before any of these operative principles began to rise. Boyle's Scept. Chemist.

about its surface; and if held near to the hand, a vapour manifestly arises betwixt the ice and the surface of the skin: which vapour proves, that water was equally distributed thro' the air, but now, coming to be condensed by the coldness of the ice, appears in a visible form. So likewise, if a third part of powder'd sal-ammoniac be put into a large glass of fair water; the external surface of the glass, tho' perfectly dry before, will now presently stand of a dew, and trickle down in drops: which shews that the invisible water of the air, like the breath in summer, is thus condensed and rendered visible, like the breath in winter. And as by these and numerous other experiments, it is certain that the air always contains water, it's impossible that bodies, exposed to the air, can be kept from water: but if it be so difficult to separate water from air, it may be no less so to separate many other bodies from water; and obtain it perfectly pure, simple and elementary. It is certain, that numerous kinds of bodies are totally dissoluble in water, both separately and conjointly, so as not to appear therein; whilst custom, which gives the law to words, calls this liquor by the name of water, tho' it be mixed and altered a thousand ways: but when we carefully examine into its peculiar nature, we shall find it possess'd of many principal properties, in common with other fluids; whence there again arises a great difficulty in finding a mark, whereby water may be accurately distinguished from all other liquors.

2. But he who enters upon this physical inquiry, should necessarily have *its mark to find* some certain mark, whereby to know water, whose nature he endeavours to find; so that by means of this mark, he may distinguish water from all other bodies, which are not water: and at length all the properties found in water, are to be referred to that thing, wherein the former mark was found.

3. In pursuance of this method, we call water a very fluid, scentless, tasteless, transparent, colourless liquor, which turns to ice with a certain degree *Water denoted* of cold; by which marks every one knows water to be denoted: if therefore we could procure such water, perfectly free from the admixture of any other body. it would be easy to examine it chemically, hydrostatically, and mechanically; and thus we might be certain, that all the discoveries made would constantly belong to the nature of water, and to no other body beside; because, by supposition, no other would be contained in it: but if other bodies be present in water, we must always remain in doubt to what kind of parts any discovered property belongs.

4. But to obtain water pure, is impossible; for, so long as the form of *Fire in water* water remains, it always contains fire, and this in a considerable quantity: *ter.* but as soon as the quantity of fire in water lessens, till the thermometer stands at thirty two degrees, water is no longer fluid, but solid ice; tho' many other bodies remain fluid in the cold that freezes water, yet may be froze by an intenser cold: on the other hand, tho' the thermometer stands seventy three degrees below the point that freezes water; yet alcohol and mercury do not freeze: whence it should seem that a large quantity of fire is requisite to keep water fluid (q).

5. But
(q. Thus Mr. Boyle: Ice is usually said to be water brought into a preternatural state by cold; but with regard to the nature of things, and setting aside our arbitrary ideas, it might *full*

Mixed with
the ingredi-
ents of the
atmospheres.

5. But all water is continually exposed to the air; which likewise enters it in a certain proportion, as we have shewn above: now, the atmosphere, we know, abounds with all sorts of volatile bodies; whence of consequence, the air must continually intermix its contents with water: an eminent proof of which we have after sudden rains, attended with thunder and lightning, and following upon long droughts; for, the rain-water, collected at this time, abounds with a great variety of particles, as chemists have often observed.

And not easily
separable
again.

6. And when the air has thus entered water, they are not easily separable again; the extraction of nearly the whole weight of the atmosphere, being required in the air-pump, before the air can extricate itself from water in thirty-three degrees of heat; and it requires a hundred and fifty degrees of heat to separate air, mix'd with water, in an atmosphere of a middle weight: whence the greatest natural heat, and the lightest atmosphere with us, are not sufficient to dislodge air from common water. Fixed alkaline salts indeed, dissolved in water, may seem to drive out the air; but at the same time they impregnate the water; and if the water be hence abstracted, yet by thus passing thro' the air again, it becomes replete therewith: but there is reason to suspect, that oil of tartar *per deliquium* does not yield air in *vacuo*; because it is strongly attractive and retentive of air: for, I have often found by experience, upon boiling strong alkaline lixiviums, that when they began to thicken and grow dry, they would suddenly swell and rise in a violent froth, and boil over, unless carefully prevented; the swelling being here stronger than in most other liquors: which makes me suspect, that true air is strongly and largely attracted by pure fixed alkali, as soon as it is removed from the fire; and that it fixes the air so firmly in itself, as not to be separated again, but by a very strong fire, or by attracting some other thing, more nearly related, as an acid suppose; with which it ferments, and thus lets go its air. Hence we see, how seldom water is to be found without air, and the things contained in air; 'tis, therefore, necessary before we come to our experiments upon water, that we expressly treat of the ways whereby water may be obtained as pure as possible; for, when once such water is found, and carefully examined, we may come the nearer to a knowledge of the pure element. To perform this the better, we must proceed slowly, and in order; examining all the properties of water successively, which can any way be found therein, so long as it remains water: and as we proceed, it will always be necessary most carefully to observe, how every property, found in any water under examination, corresponds to that water which we find to be the purest; this being, in my opinion, the only true way of pursuing the inquiry.

7.

full as justly be said, that water is ice, preternaturally thawed by heat. If it be urged, that ice, left to itself, will, upon the removal of the freezing agents, return to water; it may be answered, that, not to mention the snow and ice, which lie all the summer long on the *Alps*, and other high mountains even in the torrid zone; we have been assured, that in some parts of *Siberia*, the surface of the ground continues more months of the year frozen by the natural

temperature of the climate, than thawed by the heat of the sun; and that a little below the surface of the ground, the water, which chances to be lodged in the cavities of the soil, continues in a state of ice all the year round; so that when in the heat of summer, the fields are covered with corn, if you dig a foot or two deep, you shall find ice and a frozen soil. *Boyle's Natural and Preternatural State of Bodies.*

7. And first, we are to observe, that water has its own peculiar gravity, tho' this be extremely difficult to find; because water naturally contains many things that are lighter than the pure element itself. This appears remarkably in rain-water, and distilled-water; thus, for example, if any fermented spirit be contained in either, it renders them lighter; as on the other hand, a spirit produced from putrefied vegetables, or animals, renders them heavier: but there are many other things mixed with the air, which prove naturally much heavier than water, and render it more ponderous: for, saline, saponaceous and vitriolic bodies, largely dissolve in water, so as to increase its gravity in springs, rivers, and wells.

8. Well-water is properly the water found in the sandy stratum of the earth, or quick-springs, by digging to a certain depth below the surface of the earth, where it is not stony, till we come to a pure sand, which is in vain attempted to be dug through, fresh sand continually flowing in from the neighbouring parts as fast as any is removed; and in this sand-bed the water always rises from the bottom, and runs from the circumjacent parts; whence the names of quick-springs, and living-waters, seem to be derived; and if in a place thus dug, the access of all water is carefully prevented, except what strains thro' the sand, a pure water may be thus procured: for, as sand is only a collection of small, clean flints, of such different figures, and sizes, as to leave interstices between them; it thus strains the water, and keeps back most other substances, that were mixed with it; thus rendering the water pure and limpid: so that if there are no fine salts in the neighbourhood of these sands, the water must needs have a great degree of purity; tho' in general the case is otherwise, and salts, &c. mix with the water and increase its weight: the earth being a kind of chaos from whence all things rise, and back into which they all return. This water, therefore, is a kind of lixivium, wherein those things are held dissolved that water is capable of dissolving; whence it appears that water can rarely be obtained pure, and must differ according to the difference of the places through which it passes. Now if we compare the purest water, that can be thus obtained, with another body that does not vary its weight, as pure gold for instance, we shall find it to gold, as 250 to 4909, or nearly, as 1 to 20; to rock-crystal as 1 to $2\frac{1}{2}$; to marble as 1 to $2\frac{7}{8}$; to common air as 1 to 850, &c. (r). But as heat makes water specifically lighter, hence in all experiments about the relative weight of bodies to water, the degree of heat in the air is carefully to be observed; and since the expansions of bodies from heat are to one another as the weights of the bodies expanded, with this difference, that fluids expand more than solids; hence metals will be much less expanded than water by the same degree of heat; and, therefore, no observation of the weight of metals to water can agree, if made in different degrees of heat: but if two different kinds of water shall, in the same degree of heat, differ in their weight with respect to gold, the heavier will always contain matter in it more ponderous than the water; whence, the heavier any water is, the more it should be suspected of

(r) See Phil. Transact. N^o. 137. p. 366. p. 212.

of containing what is not water: and hence physicians judge heavy waters to be unwholesome, and the light ones to be purer and better (s); unless their lightness be owing to an admixture of spirits. Hippocrates says that light water is easy of digestion and passes off quick; and again, that the lightest sweetest and clearest rain-water is the best and most medicinal (t). Herodotus (u) has this remarkable passage: 'in *Æthiopia* they live to 120 years or longer; they eat dressed flesh, and drink milk: they have a water that nothing will float upon, not wood: and even things lighter, sink therein; and this water makes them long-lived.' But in our days we meet with no such water as this; if it could be procured, we might hence have a method of comparing our subject with it; but even repeated distillation will not afford us such a water. So that presuming this account to be true, I suspect that the woods in that part of *Æthiopia* are extremely ponderous, and their waters lighter than ours; it is certain that in *Asia*, *Africa*, and *America*, especially the hotter parts of them, there are woods that approach

to

(s) Physicians generally suppose the light and pure water the most wholesome; so that an easy contrivance to know, when water has these properties, would be of service. We have been told that water brought out of *Africa* into *England*, was found by common scales, to be specifically lighter than ours, by four ounces, in the pint. Thus many kinds of pump-water will not bear soap, and some will not dye scarlet, or other particular colours.

Dr. Hook has contrived a water-poise, which may be of good service in examining the purity, &c. of water: it consists of a round glass-ball, like a bolt-head, about three inches in diameter, with a narrow stem or neck one twenty-fourth of an inch; which being poised with red lead, so as to make it but little heavier than a pure, sweet-water, and thus fitted to one end of a fine balance, with a counter poise at the other; upon the least addition, of even one two-thousandth part of salt to a quantity of water, half an inch of the neck will emerge above the water, more than did before. *Philosoph. Transact.* N^o 197.

It is generally granted, that those waters, *cæteris paribus*, are the best as well for wholesomeness, as other various oeconomic uses, &c. that are free from saltiness; which is an adventitious, and in most cases, a hurtful quality in waters. Mr. Boyle, therefore, contrived a very extraordinary method of examining the freshness and saltiness of waters, by a precipitant, which could discover one part in 1000, nay 2, or 3000 parts of water. This he proved before K. Charles II. but he was enjoined to keep it a secret. *Ibid.*

I have often found an unsuspected sea-salt in water, by pouring therein a solution of fine silver, made in *aqua fortis*: for, as common salt, or its spirit, will precipitate the me-

tal in form of a white calx in such a solution; I imagined, if the water, in its passage thro' the earth, gained ever so few saline corpuscles, they would act, tho' faintly, upon the dissolved particles of silver; and accordingly, upon their mixture, a kind of whiteness immediately ensued. This experiment has taught me to avoid such water, and to use in its stead rain-water, or that, which had been freed from its salt by gentle distillation. *Boyle's Useful. of Exper. Philos.*

Divers means have been attempted for making sea-water sweet; Mr. Haughton had a secret for this purpose, which he at length discovered in the history of the royal academy. It consisted in first precipitating the water with oil of tartar; then distilling; and lastly, filtrating it thro' a peculiar sort of earth, which he mixes with it, and suffers to settle to the bottom. After the three operations, the water, remains perfectly wholesome.

Dr. Lister holds, that salt-water is rendered fresh by the breath of plants, growing in it; and accordingly gives us an experiment, wherein some common-sea-weed, or *alga marina*, being set in a glass body of salt-water, distilled every day, without any fire, a quantity of pure, potable water. *Phil. Trans.* N^o 156.

The thawed ice of sea-water is often used at *Amsterdam*, for brewing. And *Bartholin*, in his book *de nivis u. u.*, confirms this relation in the following words: 'Tis certain, says he, that if the ice of the sea-water be thawed, it loses its saltiness; as has been lately tried by a professor in our university.'

(t) Hippoc. de aëre, aquis & locis, §. 16.

17.

(b) Herod. lib. III. c. 125.

to the hardness of iron, and the weight of stone; whence, they are called iron-woods. Box-wood, long kept, with us is extremely solid and ponderous; so is that particular kind of oak, commonly called iron-oak; and of the best lignum-vitæ the *Americans* make their weapons: whence we have a confirmation of the truth of what he relates. Indeed, later observations confirm nearly all the relations of this historian; tho' such as are ignorant in natural philosophy, esteem them as false, or fabulous: but the lightest water, that we can at present procure, either by nature, or art, is constantly heavier than all the known wines, or liquors procured by fermentation with water and vegetables.

9. Another property of water, in common with other liquors, is its fluidity; which is so great, that its smallest particles recede from each other with a very little heat or motion: whence, experiments, carefully made, may shew what proportion exhales in a given time, from a known surface of water, with a given heat; whilst the water is not disturbed by winds. Where we are to observe, that, *ceteris paribus*, water exhales the more, the purer it is; and the less, the more it abounds with salt; so that, if perfectly pure, there is scarce any cohesion between its parts: which being drawn out, they do not run in long, ropy veins, or spirals, but rather dissipate into a fine dew. Thus, when distilled with a gentle heat in clean glass-vessels, it rises in a tepid vapour; which striking against the sides of the glass, returns to water; and running down the internal surface, never appears in veins, as oils and spirits do, but resembles dew-drops: whilst sea-water, on account of the salt and bitumen mixed among it, does not so easily separate into its particles, as fresh; whence springs, brooks, rivers, lakes and ponds exhale more in proportion than the sea. How much the sea, and fair water exhale, and with what difference, is computed by Dr. Halley (*). A small degree of heat, so as not to raise a sensible vapour, occasions a copious exhalation from water; whence, by the heat of the sun, and the action of the winds, water is continually kept in motion, carried off and dispersed. And hence appears the great necessity and use both of the sun and wind; but, what makes most to our present purpose, we hence learn that the particles of water are so moveable, as to be totally separable, and resolvable by a very slight cause.

10. This great fluidity of water is entirely owing to fire, applied in a certain degree; for, if pure water be exposed to the air, so as to be every way affected by the temperature thereof, it loses its fluidity at the thirty-second degree of our thermometer; whence thirty-three degrees of heat are sufficient to preserve water fluid: and so long as water retains this degree of heat, so long it retains motion, or exhales, and consequently flows, with this degree of heat. But as this degree of cold may naturally, as we saw in the history of fire, be augmented to the first degree; and as heat seldom naturally rises to eighty degrees; hence it appears, that water may become and remain ice, within the limits of $\frac{1}{2}$ part of the greatest natural heat; and with the other $\frac{1}{2}$ become and remain water: which could not easily be credited, unless thus satisfactorily proved. And doubtless, there must be some

L 11

weighty

(*) *Phil. Trans.* N^o. 189. p. 366.

weighty cause in nature, why water should only remain water in that degree of heat, and ice in a less.

*Its fluidity
not to be
heightened.*

11. And when water once obtains its first fluidity with this determined degree of heat, it retains the same invariably, in all greater degrees of heat; so that no art, hitherto known, can render it more fluid, how great a fire soever be applied: hence, water either exists in its own fluid state, or in the form of ice; whilst the action of fire cannot divide its particles farther, but only set them loose; upon which, the water immediately becomes a fluid, as its nature permits. Thus Sir *Isaac Newton* has shewn by experiments, that pendulums vibrate equally alike in hot water and in cold (y). But here we speak with respect to our senses, so far as they give us notice of the changes in bodies; and with regard to the lubricity of the parts of water, whereby they act upon each other with a determinate force, which we judge so small that fire cannot lessen it sensibly; otherwise we know, that water constantly becomes lighter and rarer from thirty-two degrees of heat, up to two hundred and twelve; and on this account gives less resistance to the motion of the same body of the same weight. The scale of the rarification of water we have already given in the history of fire: thus boiling-water possesses $\frac{1}{17}$ th more space; but this makes scarce any sensible difference in the motion of a pendulum, whilst itself also rarifies by the boiling water, and renders so small a difference still less.

*The smallness
of its parti-
cles.*

12. If we reflect upon the ultimate particles of water, we shall find them so extremely small as not to be measured: a single particle not being an object of sense, however assisted; nor manifesting its bulk by uniting with other things. In the history of air we have shewn, that water may pass thro' smaller pores than air (z); as, for example, thro the invisible pores of wood, where no elastic air can enter: tho' this does not shew the real smallness of the single particles of water, but only their penetrating power, which may depend more upon the figure, than the size of the particles. Nor can we here argue from weight: as a spherical particle of gold may pass, where the same particle beat into a thin plate could not. I farther doubt, whether a single elementary particle of air be less than a single elementary particle of water; because, particles of air may lodge between the contiguous particles of water, and yet the water remain incompressible, as was above shewn in the history of air.

*Its penetra-
bility.*

13. Tho' we cannot determine the size of the component particles of water, yet we know no fluid more penetrating, if we except fire, (which pervades all things) the magnetic effluvia, and light. It's true indeed, oil will sometimes soak thro' casks, that would contain water; but the reason is, that the oil dissolves the rosin of the wood, and so both run thro' together: whereas water, not dissolving the rosin, does not sweat thro'. So again, water

(y) See *Newton*, Opticè, p. 312.

(z) M. *Hombert* is of opinion, that water enters such narrow pores as will not admit the air, only because it moistens and dissolves the glutinous matter of the fine fibres of the membranes, and also renders them more pliable and diffractile; which are things that the

air, for want of a wetting property, cannot do. As a proof of this doctrine, he filled a bladder with air, and compressed it with a stone, and found no air to come out; but placing the bladder, thus compressed, in water, that air easily escaped. *Hist. de l'Acad. Ann.* 1700. p. 45.

water does not pass thro' paper, first moistened with oil, but oil easily will: and hence also it is, that syrups will sometimes sweat thro' casks, where water would not; sugar and water being a saponaceous lixivium, that dissolves the gummyness of wood: hence also lixiviums, especially of the alkaline kind, can scarce be confined in casks that would confine water. Upon the whole, of all true liquors, water seems to be the most fluid, and most penetrating.

14. On the other hand, all metallic vessels confine water; nor can it sink into any of the precious stones, flints, or the ponderous and hard rock-stones, glass, or sulphur; nor can it pass thro' close, hard, ponderous rosinny woods, tho' it will thro' such as are spongy, soft, light, aqueous or saline; as also, through soft, spongy stones, brick and unglazed earthen-ware; but, not thro' china-vessels, or glazed earthen-ware. Glass neither changes water, nor is changed by it; and, therefore, preserves it well. *Clavius* the mathematician, put some water into a glass-phial with a long neck, sealed it up hermetically, and with a diamond marked the height it rose to; and at the end of eighty years, it was found in *Kircher's* museum at Rome, still full up to the mark. Not general,

15. If cold water does not pass through any vessel that will bare the fire, neither will it pass through the same, when boiling; as we see in all the chemical distillations of water, *Papin's* digestor, and the æolipile. Some chemists, I know, are of a contrary opinion; and imagine, that water may by heat be so attenuated as, after repeated distillations, to pass thro' the substance of the glass (*a*): but we are to remember, that it is extremely difficult to join the distilling-vessels so close, as that no vapour shall pass through the luting. Others have said, that by repeated distillation, water acquires a corroding property: but in all my experiments, I do not remember, that it ever acquired any acrimony by distillation; and am convinced of the extreme difficulty of repeating distillations in any laboratory, full of vapours, and abounding with fires, and at the same time prevent losing part of the subject, and keep it from all accidental mixture. Tho' heated.

16. It is also found, that water, contained in a strong vessel, cannot by pressure be forced thro' its pores, as we see in *Papin's* digestor. For farther proof, we made the following experiments in the hydraulic machine ABCD, where AB is a hollow, brass cylinder, solder'd up close, and only opening at B, into the tube CD, which also was soldered at B, and rises in a right-angle at C, six-foot high to D, so as to leave a communication between the cavities AB, and BCD: at c there is a stop-cock E, a little above the cover AF. Now, on pouring in water at D, and opening the stop-cock E, so as to fill the vessel AB, and afterwards turning the cock E, and still pouring water into the tube d c, this pressed the water in AB so strongly, as to distend the vessel, and force the brass-cover AF upwards, tho' a great weight was laid upon it, yet not a drop of water came through the sides: nay, when water was poured in almost up to D, the soldering was burst by the pressure, and the water ran out at the cracks. From whence it is plain, that water, pressed by a great weight, cannot be forced through those pores which it would not spontaneously pass by its own fineness of parts. Or compressed. Plate 9, fig. 1.

L 112

17.

(a) See *Stahl*, in fundament. chem. dogm. & exp. p. 38. §. 7.

Made finer by
cold alone.

17. We see, therefore, that the particles of water, whilst they exist separate, can be enlarged by no other cause but fire alone, which has this power universally upon all bodies; and that these particles cannot be diminished but by the absence of fire: but this sensible diminution in the particles of water goes no farther than to two and thirty degrees of heat, when water becomes ice; and the farther contraction of the particles of water, which happens in ice, cannot be observed, because the air, expelled by the closer union of the contracted particles, begins to form elastic bubbles; which, then obtaining an elastic power, dilate the ice more than it is contracted by cold. Whence we understand the reason of the observation made by masons; viz. that cold water penetrates farther into walls than hot: for, we have seen above in the chapter of fire, that water is more condensed than stones by cold; whence the pores of stones are less contracted by the same degree of cold than the particles of water; and, consequently, water, rendered as cold as possible, may pass thro' pores which it could not enter hot.

Not to be
attenuated by
fire.

18. These observations being constant, we infer that fire with all its force, however applied, and continued, to water, can never divide its component particles, or make them smaller; but on the contrary, enlarge their bulk, and strongly agitate them one among another: wherein the utmost power of fire on water terminates. I have, in still weather, collected rain-water on the top of the observatory, belonging to our university; and distilling it with a gentle fire in clean vessels, kept it close shut up for several years, without ever finding it to differ, in any respect, by hydrostatical and chemical trials.

Always in
motion.

19. But as a heat of thirty-three degrees dissolves ice into water, or keeps water fluid; hence we learn, that its parts are continually moved by this fire, whilst it remains water: for, this fire, which turns ice into water, is more than $\frac{1}{3}$ part of the greatest natural heat; and, therefore so great a proportion of heat, as is required to melt ice, must of consequence move its particles; whence, the particles of water, seemingly at rest, are conceived to be in continual motion. Thus also the solution of salts, by means of water apparently at rest, shews its particles to be in motion; tho' this solution seems rather owing to the attraction of the particles one among another, than to impulse (*b*): but a solution could scarce be made in the whole mass, unless the particles continually changed their places by a continual motion, and thence came successively in contact with the salts to be dissolved. Again, water can never be at rest in the containing vessel, while all things capable of sustaining water, are in a tremulous motion.

Immutable.

20. Hence the ultimate particles of water seem to be immutable; at least, they are so constant and unchangeable in their native figure, that no power of art or nature can alter it; and this both separately considered, or in the mass; for

(*b*) These instances of the solution of salts in water may be accounted for, on Sir Isaac Newton's principles, without supposing the particles of the fluid in continual motion. True, to effect a solution, there must first be motion; but that motion need not be supposed to have existed before the application of the

salt to the water. It may arise from the mutual attraction between the particles of the water and the salt; which, being stronger than that between the particles of the salt, may induce a separation thereof, and occasion them to recede from each other, and diffuse themselves throughout the water.

for, since water always returns the same from every operation as it was before, being neither denser nor rarer, heavier nor lighter, grosser nor finer; it appears that the particles, and their figures, must have remained the same: for, if their figures should be altered, so must their manner of contact, and consequently the pores between them; whence of consequence, a difference would always arise in their density and gravity. Thus, supposing these particles spherical, and this figure by their compression to be rendered cubical, the large spaces between the spherical particles would occasion a great degree of lightness and rarification; and there being no spaces between the cubical particles, this would occasion an increase of weight and density: but nothing of this kind is found in the æolipile; where water is violently agitated by the fire, and a strong resistance made to its exit thro' the narrow neck; whence it is highly rarified and divided; yet the vapour, thus issuing, being collected, always returns to water.

21. Hence, the primary particles of water are not flexible, or anguillular; *Inflexible.* as *Des Cartes*, and *Stairs* supposed: on the contrary, they appear to be perfectly rigid, inflexible and of an adamantine hardness. Perhaps, they are all equally perfect and solid spheres; so that if air should, in a globular form, lodge in the interstices of water, this space of the water would be to the space of the air as a hundred to seven, according to the calculation of *Cruguius*.

22. That the particles of water are absolutely incompressible has been *And incompressible.* abundantly shewn by the experiments of the academy *del Cimento*; and *Du Hamel* relates that a golden globe, perfectly filled with water, could not be compressed: on the other hand, *M. Colbers (c)* relates that a sphere of lead, filled with water, is compressible by the hammer; and the Lord *Bacon*, that a sphere of tin, being filled with water, and strongly compressed, water spirted out of it at a hole, purposely made in it. *Mr. Boyle*, and *Mr. Stairs* say, that in such an experiment, water was projected to the distance of three feet; which seems to contradict the *Florentine* experiment. But here, two things are to be regarded; and first, that air might easily insinuate itself in the filling of these vessels; which, coming to be compressed, and finding vent, might discharge the water. Secondly, the parts of the metal, squeezed by the force, might endeavour to contract themselves upon the water; which, therefore, would fly out at an orifice purposely made: so that we are not from hence to infer, that water is compressible or elastic. We may, therefore, safely conclude, that, how much soever the weight of the atmosphere may vary, water is not more or less compressed, or rendered more or less dense thereby. Hence, it is a wonderful contrivance of the author of nature, to make one of the elements, *viz.* air, almost infinitely elastic, and another, *viz.* water, unelastic. In experiments of this kind, great regard must be had, that no more air lodges in the vessel than what the water naturally contains: secondly, that the degree of heat be the same, during the whole time of the experiment; and, thirdly, that the air, naturally contained in water, is not there elastic, unless it comes to be expanded with a certain degree of heat; which drives it out by an hydrostatical force, when, as in making a vacuum, uniting.

(c) *M. Colb. Phys. General. part. I. p. 4.*

The simplicity
of water.

uniting with similar particles, it acquires an elasticity: and unless these cautions are duly observed, an error may easily happen in making the experiments.

23. The next property to be considered of water, is its great simplicity; for, when perfectly pure and elementary, there is no diversity in its parts, but an universal sameness: and we have just now shewn, that its parts are immutable in their quantity, figure, density, weight, &c. The alchemists, ever attentive to this great simplicity of water, judged that all bodies, especially the simple ones, are made of it alone, as their first matter, by means of a seminal faculty in the seed, and a quickning fire (d). Thus *Paracelsus* (e) says that water is properly an element, or the true mother of all metals. *Helmont* inculcates the same doctrine thro' all his works (f):

and

(d) With regard to this, Mr. *Boyle* observes, that he sees no necessity to conceive, that the water mentioned by *Mosis*, on which the spirit is said to have brooded, as the universal matter, was our elementary water; since, tho' we should suppose it to have been an agitated congeries, consisting of a great variety of seminal principles, and of other corpuscles, fit to be subdued and fashioned by them, it might yet be a body, fluid like water, in case the corpuscles it was made up of, were, by their Creator, form'd small enough, and put into such actual motion, as might make them all roll, and glide on one another. And as we now say the sea consists of water, notwithstanding the saline, terrestrial, and other bodies, mixed with it; such a liquor, as the former, might well be called water; because that was the nearest of the known bodies whereto it was like. But that bodies may be fluid enough to appear a liquor, and yet contain corpuscles of a very different nature, appears from exposing a quantity of vitriol in a strong vessel to a competent fire; for, tho' it contains aqueous, earthy, saline, sulphureous and metalline parts, yet the whole mass will at first be fluid, and boil like water. *Scept. Chem.*

Dr. *Lifter's* sentiment is not very remote from this: He imagines sea-water to have been the only element created at the beginning, before any animal or vegetable; or, even before the sun itself. Fresh-water, he supposes, to have arose accidentally, after the creation of these; and to owe its origin to the vapours of plants, the breath of animals, and the exhalations raised by the sun. *De Font. Med. Angl.*

Dr. *Halley* is of another opinion: He takes for granted, that the saltiness of the sea arises from the saline matters dissolved and imbibed by the rivers in their progress, and discharged with their waters into the ocean; and consequently, that the degree of saltiness is continually and gradually increasing. On this hypothesis, he even proposes a method for determining the age of the world; for, two experiments of the degree of saltiness, made at a

large interval of time, will, by the rule of proportion, give the time, wherein it has been acquiring its present degree. *Philos. Transf. N° 344.*

Tho' spirit of wine exquisitely rectified, seems of all liquors the most free from water, yet even this is by *Helmont* affirmed to be materially water, under a sulphureous disguise; for, according to him, in making *Paracelsus's balsamus farnach* (which is nothing but *sal tartari* dulcified, by distilling spirit of wine from it, till the salt be sufficiently saturated with its sulphur, and till it suffers the liquor to be drawn off as strong as it was poured on) when the salt of tartar, from which it is distilled, hath retained the sulphureous parts of the spirit of wine, the rest, which is incomparably the greatest part of the liquor, will turn to phlegm.

Corrosive spirits, says Mr. *Boyle*, abound in water; which may be observed, by entangling, and so fixing their saline part, as to make them corrode some proper body; or else, by mortifying them with some contrary salt, which will turn them into phlegm. *Boyle's Scept. Chemist.*

All birds, beasts, and fishes, insects, trees and vegetables, with their several parts, grow out of water, and watry tinctures and salts; and by putrefaction, return again into watry substances. Water, standing a few days in the open air, yields a tincture; which (like that of malt) by standing longer, yields a sediment, and a spirit; but before putrefaction, is fit nourishment for animals and vegetables. And, among such various and strange transmutations, why may not nature change bodies into light, and light into bodies. *Newton's Optics, p. 349, 350.*

(e) *Archidox. 10. chap. 3.*

(f) Tho' *Helmont* produces no instance of any mineral body, and scarce of any animal, generated of water, yet a French chemist, M. *de Rochem*, affords us an experiment, which, if it succeeded, as he delivers it, is very remarkable

and hence they affirm, that all bodies, being perfectly and radically resolved by the universal solvent, are at length reduced into elementary homogeneous water; all their particular seminal virtue being abolished (g). But this seems rather a traditionary notion than matter of experience; for after *Moses* had said, that the spirit of God brooded upon the waters in the first creation of all things, the antient *Phanicians* made water the principle of all things: the same doctrine was afterwards adopted by the *Egyptians*; and from them, *Thales* brought it into *Greece*; from whence it spread among the chemists. Hence, the followers of *Helmont* acknowledge but two simple things, viz. perfectly pure water, and perfectly pure quicksilver; whilst they hold such quicksilver to be produced from water, and resolvable into it: and hence they hold water to be the universal nutriment, whereby all things are nourished, and which can never be farther changed by art, but only by the innate power of the created seeds.

24. Another property of water is its mildness, or inoffensive nature; this *its mildness*. being so great, that when brought to the same temperature as the body in health, and applied to any part, of the most exquisite feeling, it is so far from giving pain, that it scarce produces a sensation different from that of the natural healthy juices and organs: thus it gives no pain to the eye; nor proves disagreeable, nor yields any odour, when snuffed up the nostrils, where the nerves lie almost bare: even where the nerves are stretched by an inflammation, and rendered extremely sensible of pain, warm water does not heighten it. The same holds true of ulcers, and if the nerves are eaten, or laid bare, by ulcerated cancers: where, if water be applied warm, it mitigates the pain; whereas, almost every thing else would increase it. Water has neither smell, taste nor colour, nor renders itself sensible to the nerves: it is the mildest of all the parts of the animal fluids, nor excepting oil itself, which, tho' mild, does not affect the nerves agreeably; and among all the principles, separated by art from the animal fluids, water, when pure, is the mildest: in short, water sufficiently manifest its wants of acrimony, by its diluting whatever is sharp in the human body, and thus rendering it innocent.

markable. Having, says he, found surprising things from the natural operation of water, I was willing to know what might be done with it by art; I therefore took pure water, and by a heat, artificial, continual and proportionate, I prepared and disposed it by coagulation, congelation, and fixation, till it was turned into earth; and produced animals, vegetables and minerals. The animals moved of themselves, eat, &c. and by the anatomy I made of them, I found them composed of much sulphur, little mercury, and less salt. The minerals began to grow and increase, by converting into their own nature one part of the earth, thereto disposed; they were solid and heavy.

For the generation of living creatures, both vegetable and sensitive, it need not seem in-

credible; since we find that our common water, which is often impregnated with variety of seminal principles, long kept in a quiet place, will putrefy; and then too, perhaps, produce moss and little worms, or other insects, according to the nature of the seeds, that were lurking in it. *Boyle's Scept. Chem.*

(g) *Helmont* affirms, that his alcahest adequately resolves plants, animals and minerals, into one liquor, or more, according to their several internal differences of parts: and that the alcahest, being abstracted from these liquors, in the same weight, and with the same virtues as when it dissolved them, the liquors may, by frequent cohobations from chalk, or some other proper matter, be totally deprived of their seminal endowments, and return at last to their first matter, insipid water.

innocent. If a dram of oil of vitriol was to be swallowed upon an empty stomach, it would corrode the mouth, gullet and parts adjacent; but if diluted with six pints of water, it might thus be drank with safety. And the like holds in other cases. Whence warm water is deservedly esteemed by Physicians an excellent anodyne; accordingly it stands recommended by *Hippocrates*, as a proper fomentation in violent pains.

Is a solvent.

*For simple
fossil salts.*

25. The next property to be consider'd of water, is its power as a solvent; whereby it dissolves certain bodies, and sustains them in a fluid form, uniformly intermixed among its own particles. The bodies thus dissolved by water, are the following; viz. *first*, simple fossil salts, both fluid and solid; as sal gem, sea-salt, borax, nitre, sal-ammoniac; and, as *Hoffman* justly observes, the alkaline salt of mineral-waters. So again, it dissolves the fossil acid salts, which seldom appear in a solid form, but commonly in that of a liquor; as the acid Spirits of sulphur, alum, and vitriol; which three kinds of acids, when perfectly purified and rectified, scarcely differ from one another. It is indeed difficult totally to separate water from these acids; and if this was done, they would immediately attract new water from the air, as strongly as perfectly dry fixed alkaline salts: but if the water be well separated from them, these acids may for some time be kept in the cold, in a solid, crystalline form; tho' they run by attracting the moisture of the air, or upon the application of a little more heat, whereupon they dissolve like ice into a fluid. The other simple fossil acids are spirit of nitre, and spirit of sea-salt, which always remain fluid; because the water cannot be separated from them: they being so volatile as to fly off with the degree of heat requisite to the separation. All the abovementioned fossil salts are dissolvable in water, after the manner just now intimated.

Differently.

26. But there are several remarkable differences in the manner of their solution; for, the acid salts, which usually appear in a liquid form, are already so diluted with their own water, as constantly to dissolve in any quantity of water, tho' ever so small; thus, a pound of oil of vitriol may be perfectly dissolved by a dram of water: and the like holds true of all the fluid acid salts hitherto known. But the solid fossil salts require a certain proportion of water to dissolve them; for, if too little be used, only a part of the dry salt will be dissolved, and the other part remain solid; but when these solid salts are once entirely dissolved in their due proportion of water, then the salt, so dissolved, may be farther dissolved or diluted in any smaller or larger quantity of water. And this is a remarkable property; as the solution may thus be continued *ad infinitum*; whilst a proportionable part of the dissolved salt shall always remain in the dissolving water.

27. Let it be here observed, that the more the water is shook with the salt to be dissolved, the sooner the solution is performed, and the more of the salt taken up, and *vice versa*. So again, hot water performs the solution quicker, and retains more salt than the cold; whence, water, heated only to thirty two degrees, dissolves the slowest, and retains the least quantity of salt; whilst that of two hundred and twelve degrees, being the boiling heat, suddenly dissolves and copiously retains the salt; and so in the intermediate proportions. Thus, if boiling-water has dissolved as much salt as possible,

and then be set to cool, it every moment lets fall some of the salt, till it comes to thirty two degrees of heat, when it will have dropt a large quantity of solid salt; and if now exposed to a freezing cold, it lets fall still more, till in the sharpest frost of all, the salt will be almost totally excluded, and, as long as this degree of cold continues, stick undissolved to the ice: but the first salt-water, which in the sharpest frost expelled the salt, that still sticks to the ice, will much sooner melt, by reason of the salt, than the water would do, if pure. For, as the salt, mixed with the water, prevents its freezing, so soon as pure water; so in the same degree of heat, the salt sticking to the ice, makes it thaw; whereas, without this salt it would require many more degrees of heat, before it turned to water. Which remarkable property shews, that salts have a power of preventing the parts of water from concreting into ice, by the interposition of their own particles: whence it is, that sea-water freezes much slower than fresh, and requires a much greater degree of cold, for the purpose.

27. The concretion of a salt, before dissolved in water, is called crystallization; which, therefore, must be performed by means of little water, rest, and cold; for, these are the three requisites of crystallization.

28. Again, we find, that water acts, as a solvent, much quicker upon one salt than another; thus, sal-gem is much sooner dissolved than borax. And the same water will dissolve more of one salt than another: thus, the same quantity of the same water dissolves more sal-gem than borax. Water also, when it has dissolved, as much as it can of one salt, will yet dissolve a large proportion of another, without letting the former fall. Thus, if water of a determinate heat, be fully saturated with sal-gem, it will dissolve a proportion of nitre, yet the sal-gem remain dissolved as before; and when saturated with these, it will yet dissolve some of another salt. Hence chemists and philosophers have an opportunity of inquiring farther, than has hitherto been done, into the nature of water, as a solvent for these salts.

29. Again, pure water dissolves metallic or terrestrial salts, such as all the vitriols made from metals dissolved by acid salts; whether these acids be of the fossil kind, as in vitriol and alum, or of the vegetable kind, as in verdigrease. For, it is plain from chemical experiments, that all these vitriols are made by an acid salt, dissolved in water, and a metal, dissolved in a certain manner and a certain proportion, so as together to form a crystalline glebe; and all these substances are dissolved in water after the manner above-mentioned.

30. Water, likewise, has the power of dissolving animal and vegetable salts, both native and artificial; whether they be acid, austere, saline, alkaline, compound, ammoniacal, fixed, volatile, half fixed, simple, or combined with oil; and this, whether obtained by fermentation, putrefaction, or calcination: tho' it dissolves them with the differences above-mentioned, and tartar with more difficulty than the rest.

31. To illustrate this general doctrine by experiments; (1) Put an ounce of fair water into a glass phial, let fall into it four drops of rectified oil of vitriol, shake them together, and the liquor will presently become uniformly acid in all its parts. (2) Take an ounce of rectified oil of vitriol, let fall

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into

into it four drops of fair water, shake them together; and thus also, the liquor will become equally acid throughout: whence it appears, that acid salts, being mixed, with more or less water, are equably divided thereby and united therewith. (3.) Put half an ounce of dry sea-salt to an ounce of water, stir them together; and part of the salt will be dissolved, whilst the other part remains undissolved at the bottom. (4.) To a strong brine of sea-salt, add any quantity of fair water, and they will both be uniformly dissolved. (5.) If the same experiments are made with nitre, sal-gem, borax, sal-ammoniac, salt of tartar, the alkaline volatile salt of sal-ammoniac, alum, or vitriol, the effect will be the same, as in the third and fourth experiments: whence we see, that these salts always require a certain determinate proportion of water to dissolve them perfectly; and cannot dissolve solid salts but in a limited proportion. Observe, that all the salts used in these experiments are to be well dried, and reduced to fine powder. If acid salts could be deprived of all their water, it is probable that the parts, now united in a solid form, would require a certain determinate proportion of water and heat to render them fluid; thus, highly rectified oil of vitriol frozen into solid crystals by cold, requires a certain proportion of water to prevent its crystallizing; for, if diluted with water, it will not crystallize in the severest cold: and without the assistance of violent cold, we shall scarce meet with another instance of a pure acid salt in a solid form. Hence it is commonly supposed, that acids may always be diluted by a small proportion of water; which, however, should be understood with caution, according to what we have now seen.

*The proportion
of water re-
quired to dis-
solve salts.*

32. To three ounces of pure distilled water put nine drams of sea-salt; if the water be suffered to rest, the salt will dissolve slowly, yet totally; but if briskly shook together, it will soon perfectly dissolve: add the same quantity of salt to the same quantity of water, and apply the glass to the fire; thus, the salt will dissolve much sooner than in the cold. To twelve ounces of distilled water put five ounces of sea-salt; boil them together, and the salt will dissolve: now add a little boiling water, that the weight of the mixture may be the same as at the first; thus, the salt will remain perfectly dissolved in this degree of heat. Cover the vessel close, and let it to cool; in cooling the salt will concrete, from the boiling point down to thirty-two degrees, the brine being here made as strong as possible, and dropping more and more salt every moment in the cooling: whence we learn, that water will dissolve a larger proportion of salt in summer than in winter; and more in a warm climate than in a cold one. And since putrefaction, *ceteris paribus*, is as the heat of the climate, more salt should be used to prevent this effect in a warm climate than in a cold one. Boiling water, therefore, dissolves as much salt, as it possibly can; and near the point of freezing, as little as it can: but when turned to ice, by a cold increasing to the first degree of the thermometer, it has now thrown out some salt in every degree of the increase, so as to retain very little in the strongest possible natural cold: which shews, that there is a certain native force in the particles of water, whereby, with the assistance of heat, they may be so separated from one another, as to let particles of salt lodge in their interstices; and whilst the

the heat decreases, and the water is left more to its own nature, its particles have a power of attracting one another so closely, as to lessen these interstices; so as that salts can no longer lodge therein, but must be expelled from their places, as the water freezes stronger. Whence, again, it is plain, that the power, by which water dissolves salts, depends in part upon the salt and the water, and in part upon the quantity of fire applied to both: whence I infer, that it cannot be determined, what proportion of salt is dissolvable in water, unless at the same time it be precisely ascertained, what degree of heat was applied in the solution; for, it is certain, that water, unassisted by heat, *i. e.* ice, can dissolve no salt at all. But here it is remarkable, that salt, mixed with powdered ice, thaws it, and at the same time produces a great degree of cold; as every where appears, but principally in *Fahrenheit's* experiments, mentioned in our chapter of fire: whence it follows that salt has a power of heating the coldest bodies; and this, by expelling cold from them, into the adjacent parts.

33. Whilst the thermometer stood at thirty-eight degrees, I took two ounces of pure dry sea-salt, reduced to fine powder; and found it dissolve in six ounces and three drams of pure distilled rain-water; whereby I learnt that four parts of salt required thirteen of water to dissolve it: an ounce of sal-gem, prepared in like manner, took three ounces and two drams of the same water to dissolve it; which again, is as four to thirteen: an ounce of pure dry sal-ammoniac, reduced to powder, took three ounces and two drams of the same water to dissolve it: nine drams of pure dry nitre, reduced to powder, dissolved in six ounces of the same water: half an ounce of dry borax required upwards of ten ounces of water to dissolve it perfectly: an ounce of alum dissolved in fourteen ounces of water: an ounce of *Epsom* salt dissolved in an ounce and two drams of water: an ounce of salt of tartar dissolved in an ounce and half of water: three ounces of water dissolved half an ounce of *tartarum vitriolatum*, by long shaking; three ounces of water dissolved a dram and half of the common green vitriol, by long shaking. Whence we see that different salts require a very different proportion of water to dissolve them, and that some salts dissolve quicker than others; those, which spontaneously run in the open air, dissolve very soon, and in a small proportion of water; as seeming to be more attractive, and therefore more obstinately retain their water over the fire: thus, salt of tartar, and oil of vitriol, cannot be deprived of their water without a strong heat.

34. In a saturated solution, made with three ounces and two drams of water to an ounce of sea-salt, being the utmost it would take up, I put half a dram of nitre, and found it dissolved: to another saturated solution, with six ounces and $\frac{1}{4}$ of water to an ounce of nitre, being the utmost it would retain, I put $\frac{1}{2}$ an ounce of sea-salt, and found it dissolve perfectly; and thus brines made of sea-salt, sal-gem, sal-ammoniac, nitre, and borax, may be perfectly mixed together.

35. It is observable, that before metallic vitriols are dissolved in water, they cannot be perfectly dried without changing their nature; and when dissolved, they constantly let fall much ochre to the bottom: so that by repeated solution and crystallization of vitriol in water, all the vitriol is at

length turned into ochre, and an unctuous liquor, that cannot easily be dried: whence, the easier, the quicker, and with the less water, some salts are dissolved, the stronger they seem to retain their water. There is also something particular in the solution of metals by water: for, certain salts are required to dissolve them; and when they are dissolved into crystals of vitriol, they then easily and perfectly dissolve in water, so long as these crystals retain the salt, which is the solvent to the metal; but when this saline solvent is wanting in the vitriols, water will scarce dissolve them at all, but suffers the metallic matter to precipitate; but when the metal is previously dissolved by its own solvent salt, it readily yields to water, and may thus by a gentle exhalation be reduced to crystals; wherein the metal, its solvent, and pure water, always concur in a certain proportion. By which method, metals are rendered potable; and act in the body according to the nature of the acid which dissolved the metal, and still adheres thereto; as well as according to the nature of the metal itself, which in each metal is peculiar; so that the action of vitriols depends upon these two principles, united with water: and of this kind are the vitriols of gold, lead, silver, copper, iron, and tin.

Water does not dissolve all metallic salts.

36. But this rule does not extend to all the semi-metals, which, tho' first dissolved in their acid solvents, so as to appear in a saline form, cannot therefore be diluted with water, like the salts of true metals. Thus, pure regulus of antimony perfectly dissolved in the rectify'd spirit of sea-salt, adhering to the mercury sublimate in the distillation of butter of antimony, is a true vitriolic salt, made by the regulus dissolved in spirit of sea-salt: whence one might suspect that this butter would dissolve in water; but on the contrary, as soon as water touches it, the acid solvent quits the regulus, mixes with the water, and lets fall the metallic calx entire: whence the general rule is to be limited, or not extended beyond its proper bounds.

Dissolves alcohol and fermented oils.

37. Water dissolves alcohol, tho' not spontaneously, but by being shook therewith; for, otherwise water, being gently poured into alcohol, passes thro' it to the bottom, the alcohol floating at the top; nor does the water dissolve it readily by little shaking, but it still remains dispersed in unctuous veins through the body of the water; tho' by continued shaking they perfectly unite: as alcohol, therefore, is a pure vegetable oil, produced by a perfect fermentation, its nature is thus changed, so as not only to burn in the fire, but to mix with water. Whence we learn, that oils themselves, being thus changed, may perfectly unite with water; but the sooner and the easier, if they be first previously dissolved with a proportion of water: for, common brandy mixes easier than pure alcohol with water.

Water saturated with salt, does not dissolve alcohol.

38. But it is to be remarked, that water, perfectly saturated with dissolved salts, cannot be mixed with alcohol, tho' ever so violently shook together; but on the contrary, they repel each other more strongly than any other known liquors. Thus if oil of tartar *per deliquium*, put to pure alcohol, be ever so violently shook together, they immediately separate upon standing; the alcohol totally rising to the top, and the other falling to the bottom: and even boiling will not make them unite in any measure.

39. But here we are to observe, that if water be saturated with a salt that easily separates from it, alcohol will dissolve the water, and the salt fall to the bottom. Thus, if to a saturated solution of *Epsom* salt in water, alcohol be poured, and the vessel shook, the mixture will grow opaque, white, turbid, and let fall the salt in little crystals. So again, in making the *offa Helmontii*, where water is saturated with the alkaline volatile salt of sal-ammoniac, if an equal quantity of pure cold alcohol be added, and the liquors be shook together, they instantly form a white, solid mass; from whence a little water, that was attracted by the alcohol, is soon afterwards separated.

40. Water has also this remarkable property, that if mixed with alcohol, wherein a distilled oil is dissolved, it separates the oil from the alcohol. Thus, if oil of cinnamon be dissolved in pure alcohol, and water be let fall into this solution, the mixture presently becomes white and opaque, tho' it was perfectly pellucid before, and the oil separates, and gathers together: whence it appears, that water unfits alcohol for dissolving these oils; that alcohol easier unites with water than with them; and lastly, that the oils, dissolved in alcohol, still remain oils, tho' at the time they do not appear as oil, but spirit.

41. Rosins also totally dissolve in alcohol: but if water be added to the solution, the liquor immediately becomes white, and the rosin is restored. The rosin, thus once dissolved in alcohol and precipitated by water, may be dissolved again, and precipitated as before, so often as one pleases; as I have learnt by numerous repeated solutions in the rosin of scammony. Camphire has been esteemed a species of rosin, but no other rosin will totally sublime in a dry form, and without suffering a change in its parts; in which respect, therefore, this differs from all other rosins: yet it perfectly dissolves in alcohol, as other rosins do, and by the addition of water is perfectly recoverable from thence in the form of true solid camphire. Hence, therefore, we see, that water attracts salt of tartar stronger than it does alcohol; and attracts alcohol stronger than that attracts oils, rosins, and camphire.

42. Again, water perfectly dissolves all saponaceous bodies, whether natural or artificial, fixed or volatile; for, all soaps are an intimate mixture of oil and alkaline salt, so as to dissolve in water uniformly, without manifesting any signs of the oil and salt separately. And it is a peculiar property of these soaps, that, when intimately mixed with oils or unctuous bodies, rosins or resinous bodies, gums or gummy bodies, gummy-rosins, and tenacious bodies composed of these, they render them miscible with water, and thus dilute and wash them away: so that water not only dissolves true soaps, but also by the admixture of soap acquires a power of dissolving such things, as water would not dissolve: whence the power of water, as a solvent, is greatly increased by soap.

43. But to render oils miscible with water, is a more laborious secret, which artists usually conceal; but if an essential oil be long and properly digested with pure alcohol, and intimately united therewith by repeated distillation, a considerable part of the oil will be so attenuated and united to the alcohol, as that both together may be mixed with water, so as to afford a noble remedy for recruiting the spirits, and scarce to be equalled by any.

any other contrivance; as by its acquired subtilty and penetrating virtue it is thus rendered capable of insinuating itself into, and acting throughout the whole frame of the body.

Water dissolves air.

44. It would scarce be suspected, that water dissolved air, unless we had proved it in our chapter of air; tho' it does this only in a certain degree and manner, whilst the air, thus dissolved and lodged in the interstices of the water, is no longer air in the sense it was before: hence, in this respect, water dissolves air, as it does salts, *i. e.* so that the single particles remain in the interstices of the water; but as soon as all the air is separated from the water by frost, by taking off the weight of the atmosphere, by fire, the sun, or the admixture of any other bodies, immediately as much other air is imbibed by the same water, as was discharged.

And some terrestrial bodies if prepared.

45. Lastly, water may, secondarily, dissolve many terrestrial bodies, which of themselves would not dissolve therein; thus the shells of shell-fish, snails, crab's-eyes, the bones, and stony concretions of animals, &c. being first dissolved in their proper solvents, may afterwards be totally dissolved in water; the same may be said of chalk, coral, pearls, mother-of-pearl, calcined stones, flint, &c.

46. It may be difficult to assign the limits of the dissolving power of water, for want of having it perfectly pure, without the least admixture of salt; as many things may be dissolved by the latent virtue of salts, that are unjustly attributed to the power of water alone: this difficulty attends metals in particular; as iron, watered with pure rain, turns to rust, and copper to verdigrise. *Langelotte* asserts, that gold may be totally dissolved by bare trituration; and *Homberg* declares, that all the metals, even gold itself, may be perfectly dissolved, rendered potable and medicinal, by a long continued triture with fair water; but as these triturations were performed in laboratories, where the air was impregnated with all kinds of volatile salts, I have suspected, that these solutions were owing to such salts; the rather, because the triturations were continued for months together: so that tho' the salts in the air were few; yet that great length of time might give them sufficient opportunity. The ancient *Hermetic* philosophers allowed indeed, that all things proceeded from and were resolvable into water, as if this was the universal menstruum; but they have not delivered the experiments upon which they build this doctrine. Water does not dissolve pure earth, freed from all adhering salt or sulphur; it does not dissolve glass, crystals, gems, nor the perfectly simple stones nor bodies, chiefly composed of these. Whence we infer, that water is not an universal solvent, but that its power is restrained to the bodies above-enumerated.

Insinuates into the pores of bodies, so as to increase their weight and bulk.

47. After seeing these properties of water, it is easy to understand, that it may readily insinuate itself into the invisible and extremely small pores of numerous compound bodies; for being ponderous, and consisting of very fine parts, their great lubricity and separability will cause it to enter easily into the smallest spaces: then again, its great dissolving power, with respect to so many bodies, enables it, in numerous cases, to soften or wash away the matter that obstructs their pores, and thus gain entrance; and this the rather, as its ultimate particles are solid and unchangeable: whence they

they have also a mechanical power of dissolving; besides the particular one, arising from their contractile and expansive force.

48. When water therefore, by this means insinuates itself into the small pores of such bodies, and thence penetrates their whole substance, it must needs increase their weight by the addition of its own substance; which in some cases is very considerable, where the bodies attract strongly, as almost all salts do; especially, the fixed alkaline kind; as likewise soaps and many solid bodies. So that, merchants sell many of their commodities to advantage, by weight in a moist cold season, which they had bought in a warm and dry one. Chemists, in like manner, have been deceived by ascribing great increases and decreases in the weight of bodies to wrong causes, whilst the effect was intirely owing to the water inherent in them.

49. But whilst water thus increases the weight of bodies, it also expands them; for it acts not barely by filling up the vacuities, but also by dilating the solid particles of bodies, or setting them farther asunder; as we learn by numerous experiments, and particularly by that curious one of the academy *del Cimento (b)*, which, because the book is scarce, we will here relate.

50. They procured two cones to be made, one of steel AB, which was solid and divided into a scale; the other of wood, which was hollowed, so that when dry, its external cavity exactly fitted the external surface of the steel one AB: but this hollow cone of wood being plunged into water and penetrated thereby, swelled so, internally, that the steel cone AB could not now enter its cavity. Again, the cone of wood CD, which when dry exactly fitted into another hollow cone, being moistned with water, swelled so, externally, as not to enter the cone it entered before: whence we have an ocular, mechanical demonstration, that wood penetrated by water, is expanded in all its dimensions; and hence, surprising effects may arise from water insinuating itself into dry bodies. See plate 3. fig. 2.

51. When once water is intimately mixed with other bodies, far removed from an aqueous nature, it may concrete with them in a surprising manner; so that one would not suspect water to be in them: thus, for example, if three pounds of sea-salt be decrepitated, and almost fused, then reduced to powder, and mixed with thrice its weight of bole, it will by distillation in a strong fire, afford some ounces of a strong spirit of sea salt, which after M. Homberg's method, may be separated into water and acid salt, by means of chalk, which concentrates the acid. Thus, a kind of elementary water may be obtained from salt, after the highest degree of calcination might well be thought to have separated all water from it; but, it seems, that the water here was so closely united to the particles of the salt, as not to be separated but by the utmost violence of fire. The like holds true also of sal-gem, spring-salt, and nitre: even alum and vitriol, reduced to perfectly dry powders by calcination, yield acid spirits upon distillation, which may afterwards be separated into a large proportion of water, and a small one of acid salt. Concrete with saline b. dies.

52. Dry sulphur contains much water; for, in burning it yields an acid spirit, which may be separated into pure water and an acid like rectified oil of With sulphur.

(b) Experiment 184.

of vitriol: consequently, the acid, which when united to a vegetable oil makes sulphur, contains true water, that enters the composition of sulphur; so that the perfectly dry and combustible body of sulphur, has water for a constituent principle. I acknowledge that the water concealed *in ol. sulph. per campanam*, may in part proceed from the air whilst the sulphur is burning; because more spirit is obtained by this operation in a moist air. At the same time we see that oil of vitriol and of sulphur constantly contain water; and, therefore, since oil of vitriol enters the composition of sulphur, water also must enter. Whence we infer, that water enters the composition of all sulphurs and salts, lies concealed in them, and may be thence forced out.

*With terrestrial
bodies.*

53. It seems more improbable, that the soft and fluid body of water should enter the composition of the hardest and dryest bodies, and adhere so strongly to them as to manifest no signs of its being there, nor be separable from them, till forced away by extreme violence of fire; tho' even by this means, we cannot be assured that all the water is driven from them: for, the ultimate particles of water, being solid, ponderous, incompressible, and immutable, and having once firmly fixed themselves in other bodies, are so riveted thereto, as scarce to be separated again by any art or force. This peculiar property of water we have already considered, at our entrance upon the present chapter; where we saw how universally it contributes in nearly all the works of nature: we next proceed to shew, that the hardest and most ponderous bodies principally owe the cohesion of their parts to water alone, which here acts as the strongest glew in nature.

54. When alabaster is calcined to a lime, it becomes a light, soft and fine powder; but if mixed with a proper quantity of water into a soft paste, it immediately acquires a stony hardness, and with difficulty lets go its water: so potter's clay, being baked and reduced to an impalpable, loose powder, then mixed with water into a paste, and baked in a potter's kiln, it thus makes pottery, of a stony hardness, capable of holding water: understand the like of lime-stone, and the shells of fish. Sand and lime will not stick together, but with water they make mortar, wherein bricks being laid, it will last for ages; as we see in buildings: so in the making of glews from starch, meal, animal-skins, and fish, water is a necessary ingredient. All these instances considered, the chemists seem to have been right in asserting, that water concretes with the hardest bodies. This with me is a principal and grand property of water, that deserves to be well considered by chemists. Who would have suspected that water should concrete with the primary particles of bodies, connect them with one another, and thus contribute to the substance of all things?

*With the solid
part of ani-
mals.*

55. Again, it appears that the dryest and hardest parts of animals, as the hair, nails, horns, teeth, bones, ivory, &c. acquire their requisite hardness by the accession of water; for, if any of these substances, tho' kept so long as to become extremely dry, be distilled in a glass retort, with a violent fire, their greatest part will prove to be volatile, and only a small part remain fixed: but the volatile part is almost totally liquid, except the salt, and separates into oil, salt, and a large proportion of water; which shews that

that water was intimately united with these hard substances, and helped to consolidate them; for, when all water is separated from them by the force of fire, nothing but loose ashes remain behind, or a brittle substance, easily converted, by triture, into a loose powder; especially after these substances, that were left black in the retort, are calcined to whiteness in an open fire: and if an entire bone be calcined to whiteness, so as to appear brittle and crumbly, and then be plunged into water, it attracts the water into itself, with a hissing noise, and thus recovers its lost weight, and former hardness, and cohesion of parts. Hence we infer, that water, tho' it does not afford the ultimate matter in producing the solid parts of animals, yet serves as a cement in sticking the parts together; making a portion of the concrete; and adding to its bulk.

56. One would not easily imagine, that water constitutes the largest part of oils; yet M. *Homborg* has shewn, by careful experiments, that distilled oils, by a chemical analysis, resolve chiefly into pure water (i); and pure alcohol is said by *Helmont* to have had one half of itself converted into elementary water by the attraction of salt of tartar: thus much is certain, that in burning, alcohol shews it contains much water; as we saw in the chapter of fire. Hence it is plain, that water is largely diffused thro' many kinds of bodies, and concretes firmly with them. With oils, and alcohol.

57. But we are not hence to conclude, that water is the only substance from which all sensible bodies arise. Some eminent chemists have asserted that water, purify'd and hardened by long frost, is condensed into rock-crystal; and pretend that this is found true, in the frozen mountains of *Switzerland* towards the north, where ice, never thawing, is said to be thus transmuted (k). But it has been found that water, rendered colder by forty degrees than it is never naturally found, will presently thaw; nor could this cold ever contract and condense water so as to give it the weight and density of crystal, much less the solidity of the diamond: whence it is by no means probable, that precious stones should ever be formed from frozen and condensed water; but gems, like all other bodies, rather grow from their own peculiar seed. Tho' the Lord *Bacon*, therefore, affirms, that there is no nutrition without water, and that no substance could grow without it, yet this holds principally true of vegetables and animals; whilst the contrary obtains in metals: unless by water we should here understand mercury; for, the adepts commonly call quicksilver, the metallic water, or simply water, or their own sea: tho' it seems scarce credible, that water can be rendered fourteen times heavier than it is. But in animals and vegetables, water truly constitutes a large part of their aliment, and intimately connects their constituent particles together; so that in a great measure they consist of mere transmuted water: yet it has hitherto been shewn by no just experiment, that water alone can afford all the parts of these bodies; notwithstanding *Helmont's* experiment of a flint nourished by water, and Mr. *Boyle's*, of plants increasing their weight by watering. All bodies proceed not from water.

58. It has been found by a careful inquiry, that water is the principal vehicle whereby the nutrimental matter of animals and vegetables is conveyed

N n n

and

(i) See *Hist. Acad. reg. sc.* 1703. p. 37. Du *Hamel Hist. acad. sc.* 372. (k) See *Paracelsus* and the Academy del *Cimento*.

and distributed; and that the water itself is not a real nutritious matter; but impregnated with various heterogeneous particles: for, the purest rain is always full of vegetable particles. All water, the more impregnated it is with unctuous, earthy particles, the greater weight it adds, in the same time, to the vegetables it waters; whilst the greatest part of the mere water, which enters plants, soon exhales from them again; at the same time that the fat earthy particles, mixed with the water, are consumed in the vegetation of the plant; as Dr. Woodward has shewn by careful experiments (1). It is however plain, that water in some sort intimately unites with the solid parts of bodies, and concretes with them into the same mass; so as not only to serve as a vehicle, but enters as a constituent part of vegetables and animals. Whence the ancient chemists called water the universal wine, drank of by all vegetables, animals, and minerals; and in this sense we may properly say that all things proceed from water.

Some bodies
repel water.

59. There are some bodies that repel water, without causing any motion in its own substance; and the like property is found in some fluids, as well as some solids: thus oils repel and do not mix with water, tho' shook together, but separate from it, and collect themselves into spherical or spheroidal drops, driving the water from them in the shortest possible way: balsams and rosins, melted by a gentle fire, have the like property; with this difference, that the more subtile the oil, or unctuous body is, the less it repels the water, and *vice versa*; so that becoming extremely thin, such bodies may intimately mix and unite with water.

60. Some solids also repel water; especially, the more solid ones, that take a fine polish; as also the hair of animals, the feathers of birds, spiders-webs, silk-worms-nests, &c. on the external surface whereof, an unctuous crust is lodged, participating of the nature of oil, on which account they repel water; for, if deprived of this unctuousness, by being boiled in a sharp lixivium, they do not repel it so much: but a well-polished surface is here alone sufficient; as we see in polished metalline plates, which water will not stick to, but roll off from; whereas, when rough or scratched, the water adheres to them. Ivory and bone, when their surface is unpolished, imbibe water; but when polished, repel it: this indeed may be owing to the pores being filled up in the polishing; and hence perhaps it is, that the soft bodies of fish are covered over with polished scales, and well defended with a subcutaneous fat to secure them against the water, in which they live, and by which they might otherwise be soon dissolved; for, after death, their scales being relaxed, and the unctuous matter failing, the water soon dissolves their flesh (m).

Rain-water.

61. Having thus considered the general properties of water, we next proceed to the various kinds thereof; and first, let us consider the nature of rain-water, which we may call the lixivium of the atmosphere, as containing all kinds of particles, which float in the air: and what these are, may be found in the preceding history of the atmosphere; where we have shewn, that all kinds of volatile bodies abound therein. Now, bodies become volatile either spontaneously, or by means of fire, fermentation, putrefaction, mistion, separation

(1) See *Philos. Transact.* N. 8. 253. p. 193.

(m) See *Ad. Lips.* 87. p. 160. *Perauld. Eff.* V. III p. 297.

separation and effervescence. Whence salts, spirits, oils, soaps, and even metals themselves, may sometimes lodge in the air, according to the difference of the causes which excite them; and these are principally the sun, and subterraneous, culinary or mechanical fires, used by artificers; whence rain may greatly differ from itself; and again with respect to the soil, from which the matter of rain is raised. So likewise rain may be very different, according to the different seasons of the year: thus, the rain in spring, summer, autumn, and winter differs in its substance and effects. For example, rain-water collected in the spring, is the fittest for fermentation; as being impregnated with such effluvia of the earth as were bound up in the winter, and are now resolved by a genial warmth, dispersed thro' the air, and mixed among the rain. So the different states of the atmosphere greatly alter the nature of the rain; thus what falls after a long drought, is very different from that which falls at the end of a long rainy season. The meteors also here occasion a great difference; thus the water of a thunder-storm, greatly differs from other water. Again, winds carry the water of the air from one place to another, and along with it the exhalations of different and very distant parts of the earth; which exhalations may thus be variously mixed in with the water of rain from different quarters; and sometimes form an unusual compound, so as to occasion great fertility, &c. We learn by frequent observation, that the rain falling in a hot season, being received in clean vessels, and kept for some time, will putrefy; but I know not whether rain-water has ever been observed to grow acid: for my own part, I never found it do so; but when it putrefies, it may easily be corrected, so as to become potable and wholesome; viz. by boiling it, which kills the animalcula it contained; then suffering it to subside, and adding a little pure acid to what is decanted. And it has been usefully observed under the æquator, and within the tropics, where the waters putrefy most abominably, and generate worms, that the health of the sailors may be preserved by this treatment of the water: tho' a small proportion of spirit of vitriol would here preserve water from putrefying and breeding worms; and this without rendering it unwholesome. Experiments purposely made upon rain-water could never bring it to ferment, so as to afford inflammable spirits by distillation: and, I have found by experiment that rain-water, collected in a high and clean place, and preserved in pure vessels, abounded with little seeds that produced a fine green kind of water-weed: for upon keeping such water in clean glasses, I discovered that small green specks first appeared and grew gradually larger; when at length being examined by the microscope, I found it to be a true weed. If it be said, that these seeds fell into the water from the air, this does not alter the case; for, thus also they may be contained in rain, which falls through the air. So likewise the invisible seeds of mosses, dispersed in rain, occasion the appearance of little plants in the water; but what grows most copiously herein, is a mucilaginous, or ropy substance, as it appears to the naked eye; but when viewed through a microscope, resembles a grove of little mushrooms. These are the principal native plants of water, and which scarce any care can prevent from growing therein; tho' they appear more at one time of the

year than another, and thus affect the water differently. Rain-water also, collected in the spring or summer, is found to be full of the eggs of minute animals, which appear to hatch therein, and may be seen by the microscope, especially after the water has stood long exposed to the sun and the open air: what numbers of them appear in a single drop of such water, may be learnt from *Leeuwenhoek's* Observations.

How obtain-
ed pure.

62. The purest rain-water, therefore, from hence appears to be no homogeneous fluid; but nothing is stranger to me than that, when kept in a close vessel, it should so soon generate little white clouds, which gradually grow larger, more numerous and more opaque; and these degenerating into a slimy substance, turn the whole water ropy; whence at length it deposits a feculent matter, changes its colour, taste and odour, and thus grows thick, vapid, musty and disagreeable. This is the nature of pure rain-water, which therefore is far removed from a perfect simplicity, as being subject to so much foulness; and yet this water is esteemed the lightest of all waters, and truly distilled by nature, as being raised from the surface of the earth by the mild heat of the air; and, being raised much higher therein than any chemical distillation could carry it, 'tis returned back again without partaking of the foulness of any vessel: so that chemists can scarce any way obtain by their distillations, a purer water than nature thus commonly affords it; as may easily appear from a consideration of the water which chemists distil, the vessels and the fire they use, the small height of the distilling vessels, and the air wherein the operation is performed: all which being considered, 'tis no wonder I should have found, by careful experiments, that distilled rain-water is not lighter than the natural, but hydrostatically the same. Snow-water is found to be the lightest of all rain-waters (*n*); and therefore snow-water, received at a great height from the earth, is the purer or freer from gross and ponderous parts: and if a long-continued, sharp frost shall, at a great height, convert water to snow, after a long-continued, clear and dry season, the snow, thus formed, will be of the purest kind; especially, if no wind has disturbed the air, or intermixed any foreign volatile particles with it. Thus, if, in these circumstances, snow should fall upon a barren, sandy mountain, in a desert far remote from any place inhabited by men, and the snow should lie deep; if the upper part be now carefully collected, it will thus be obtained as pure as possible; for, it will scarce contain salt, oil or other foreign substance: so that water procured by melting this snow, will greatly differ from all other water, and be extremely pure, unchangeable, or capable of being kept for years, as an excellent remedy against inflammations of the eyes. The ancient alchemists have said, that from such pure snow there may, by a secret art, be obtained a very red substance, that by the force of fire may lie intimately buried and concealed therein. This snow, falling for ages upon the same spot, is, by *Olaus Rudbeckius* (*o*), said to leave a thin crust behind it; which, increasing in time to a sensible *stratum*, renders the earth extremely fruitful. And so much for the method of obtaining the purest water possible.

63. This

(*n*) See Mr *Boyle*, *Med. Hydrost.* p. 104.

(*o*) *Atlantica*, p. 128.

63. This water, being long digested, putrefies and grows fetid, and by distillation affords an oily spirit in some degree inflammable; but if digested, putrefied, distilled and concentrated, it yields a fragrant spirit, that silently dissolves the body of gold (p): if contained in casks, and putrefied by heat between the tropics, it afterwards loses its bad scent, and becomes clear again by rest (q). That rain is the most impure which falls in a hot, windy season, near great cities, which stand low, and abound with the fetid exhalations of animals and vegetables; especially, if the air be thick, foggy and fetid, so as to affect the nostrils and the lungs by its noxious vapours, which frequently appear and disappear without any manifest cause. We have found by experience, after long continued drougths and heats, if thunder-storms have followed, the rain, that falls heavy at this time, being received in clean vessels, yields a froth, which seems to contain something of a fine nitrous salt; and when it falls in stormy whirlwinds, it has sometimes been found fetid, and the cloths wet with it have in 24 hours after been full of worms (r). Whence we may understand the cause of the earth's fertility; as such rain contains a subtile matter, capable of affording particles to nourish the solids and fluids of vegetables; at the same time acting as a proper vehicle to convey whatever is requisite for their nutrition.

64. If the snow-water, collected as above, be once distilled with a gentle heat, in clean and tall vessels, it may be esteemed perfectly pure; especially, if the operation is performed in a clean place, free from all smoke and odour. And this, of all the ways I have tried, is the best for obtaining pure water: tho' some for the purpose, I know, draw it over gently from fixed alkaline salts, to hold back the acid, oily and earthy particles; but the alkali thus communicates something lixivious to the water: whence others, in the same view, distil it from sal-gem, sea-salt, nitre, &c. But the water thus distilled is always impregnated with something foreign; and tho' it be successively drawn off from different substances, as acids, alkali's and neutrals, 'tis not thus rendered the purer: and when the purest water boils over the fire, it still retains its dislodging virtue above described; and this tho' it be several times distilled.

65. We now proceed to enumerate some marks in the purest distilled rain-water, whereby to distinguish it from other kinds: and first, upon mixing with other waters less pure, and opaque whiteness immediately arises, tho' both of them were perfectly limpid before their mixture: and if fine soap be dissolved in this purest distilled water, it mixes uniformly without curdling; whereas it curdles with the waters less pure. So again, perfectly pure water, thrown upon wax, or sprinkled upon linnen to be whitened, gives them a perfect whiteness; but if the water be impure, it leaves them less white: it grows hot and cold sooner than other water, and is never improved by boiling. Pure gold and silver, being melted separately or conjointly, and poured into this pure water whilst cold, pass quietly thro' it, and are found granulated at the bottom: but iron, tin and lead, melted and poured into water, enter it with a violent explosive motion, and immediately fly from it like shot, in a dangerous

Marks of pure
distilled wa-
ter.

(p) *Ass. Lips. An.* 1690. p. 86.

(q) *Phil. Transf. Abridg.* Vol. II. p. 326.

(r) *Phil. Transf.* N^o. 127. p. 652. and A.

bridg Vol. V. p. 171.

dangerous manner: and copper, treated in this way, explodes with the violence of gun-powder; of which there are terrible examples. This wonderful property of water seems to me unexplicable upon any known principle. Pure, simple rain-water may, in a proper sense, be esteemed the mercury of animals and vegetables; as being not unlike quicksilver in simplicity, and, according to *Helmont*, the first principle from whence all things proceed, and into which they are ultimately resolvable.

Spring-water.

66. All spring-water arises from rain, raised by heat from the surface of the terraqueous globe into the air; which thus abounding with water, and impinging by night against the cold sides of high and extended mountains, the watery vapours are here condensed into drops, after the manner of distillation: whence proceed rivulets, springs, &c. as was mentioned in the chapter of air. And hence we learn, that spring-water is never purer than rain; yet when this rain, turning to spring-water, passes over sand, or places full of fine, clear flints, it may there deposite its heterogeneous parts, and at length run pure. This method of percolation nature uses to render water perfectly bright and simple, after it has been foul'd by washing the places it passed through: and thus we have another way of obtaining water as pure as possible. But if this spring-water passes thro' places containing a matter easily dissolvable by water, it thus becomes impregnated therewith; and tho' it should afterwards run thro' beds of stone or sand, or even mountains themselves, it might also carry such dissolved particles along with it; and hence springs, rivulets and lakes partake of the nature of such matters thro' which the water flows (*s*). Whence nothing particular can be affirmed of spring-water, without a due regard to the soils it passes thro', as whether they be aluminous, saline, saponaceous, vitriolic, &c. Thus there are numerous medicinal cold springs, which *Hoffman* has shewn to be alkaline, volatile and spirituous; and numerous hot ones abounding with sulphur, and greatly differing from the former; tho' both these sorts are called spring-water, some proving medicinal and wholesome, others pernicious and poisonous; some also are of a petrifying nature, as particularly in the petrifying cave of *Burgundy*, about a mile from *Quingey*, where the water dripping thro', petrifies into statues of all kinds of figures (*s*). Yet what is very remarkable, these petrifying waters do not generate the stone in those that drink them (*u*). Hence we learn, that nothing can be pronounced universally of the clearness, weight and virtue of spring-water; but that every spring must be examined, in order to discover its nature; and this appears from nothing more plainly, than that if any spring-water be boiled for some time, then suffered to rest and grow cool, it deposite a sediment. But nothing seems to me more extraordinary in the history of spring-water,

than

(*s*) ' Some springs are much more copiously
' impregnated than others; and therefore will
' bear a greater dilution by rain water: Thus,
' tho' I have found more than one of our *Eng-*
' *lish* ferruginous springs, especially those
' near *London*, too much weakened by water,
' that rained into them; yet upon carefully
' trying how much of that fluid some *German*
' spaw water, which came very well condi-

' tioned to *London*, would bear, it appeared,
' that when this was diluted with no less than
' thrice its weight of rain-water, it still re-
' tained strength enough to produce a purplish
' colour, with fresh powder-galls.' *Boyle's*
Nat. Hist. of mineral waters.

(*t*) *Journ. de Sav.* an 1688. p. 432.

(*u*) *Hist. Reg. Ac. sc.* p. 91, 92.

than that it should not be found in some places dug a very great depth into. Thus Dr. Plot, in his natural history of *Staffordshire*, describes a pit decending perpendicularly 2600 feet; where, tho' he let down a rope of this length, he could neither find bottom nor water at so great a depth: how solid, therefore, must the bottom and sides of such a pit be, that will not suffer water to burst thro'?

67. As rivers proceed from springs, what we have already said of spring-water may be applied to river-water; with this difference, that spring-water generally runs under ground, whereas that of rivers is exposed to the open air. Whence, whatever falls from the atmosphere, or is conveyed by the winds; whatever vegetable or animal matter falls in their way, or whatever fish and amphibious creatures deposit, all comes into the course of rivers; mixes with their water, and may there diffuse itself, putrefy and dissolve. And as all rivers rise from mountains, and at length disgorge into the sea, rivers can never rest, as being perpetually running down to the ocean; and as in their course they pass thro' different places, viz. woods, cities, &c. in each of these places the water must be of a different kind; so that nothing particular can be affirmed of this water also, without considering the difference, that may arise in every place, where new substances may be mixed with it. Rain-water easily mixes with it; and at different times and places, animal, vegetable and fossil substances, unite therewith: no wonder, therefore, that river-water, taken up by the *English* at *St. Iago*, and kept in casks, should, near the island *Borneo*, be so changed with the heat of the climate, as to discharge a vapour that took fire at a candle; the water at this time being fetid, but after settling, again becoming sweet (*). So *Thames*-water (†), and the water of *New-York* river, grew intolerably fetid in the cask in eight days time; but became sweet, when arrived at *Virginia* (‡): so again, the *Thames*-water, contained in casks and carried into hot countries, was in eight months time converted into a fetid, spirituous liquor, the vapour whereof burnt like spirit of wine; but upon opening the cask, and admitting the air, it became sweet in twenty-four hours: or if the water was strongly shook in the cask, it became sweet and potable in five hours; and even in its fetid state, it is said to be wholesome (d). If sea-water be distilled, and mixed with river-water, it does not putrefy (e). In the kingdom of *Congo* there is a river, which, when agitated, yields a froth, that, being received by straw spread upon the shore, concretes into a tenacious

(*) See *Phil. Trans.* Abridg. vol. 5. p. 271.
(†) That the *Thames*-water, when carried long voyages, and into hot climates, will have a very offensive scent, the common putrefaction of stagnant water may persuade us: yet 'tis found, if that be kept long enough, tho' in the same vessel, and a hotter climate, it will at length grow sweet and potable again. Several other waters have the same faculty of recovering after putrefaction, as well as that of the *Thames*, whereto 'tis usually supposed peculiar. And

having had the curiosity to try how the roughest kind of water, that will not bear soap, might be remedied; an industrious person, whom I employed, assured me he had met with pump-waters, that barely by standing a few days, would gain this property. *Boyle's Usefulness of Exper. Philos.*

(‡) *Phil. Trans.* No. 127. p. 652.

(d) *Phil. Trans.* No. 268. p. 838. and *Trans.* Abridg. vol. 3. p. 547. *Mem. Ac. roy. sc.* vol. 1. p. 404.

(e) *Du Hamel de menstruis*, p. 412.

cious substance; which, when dried at the fire, grows hard like iron (c). The *Rhone* water, when well purified by standing, and properly preserved in earthen vessels, does not putrefy upon carrying, or feeling the heat of different climates; tho' it would putrefy in casks (d).

Its weight.

68. It is found by careful experiments, that rain-water, snow-water, spring-water, and river-water, when hydrostatically examined, and compared, scarce differ a thousandth part in weight (e). Whence it is not probable, that the water of a river in *Africa* should be lighter by four ounces in a pint than the water of *England* (f): it were to be wished Mr. *Boyle* had given us an exact description of this extraordinary experiment, and confirmed it by proper testimony, as the thing requires; for, if the fact was constantly to hold, what *Herodotus* says of a water in *Africa*, mentioned above, might well be received for truth. Thus much may suffice to shew the nature of river-water; for, as it contains so many different kinds of substances, a fermentation may easily arise among its parts in hot climates; and hence all the changes of fermentation and putrefaction above-mentioned proceed: doubtless, the phenomena above-recited are rather owing to these contents of the water, than to the water itself.

Standing waters.

69. We are next to consider the stagnant waters of lakes, meers, ponds, and town-ditches; as this water also is frequently employed in chemical operations. These stagnant waters differ greatly from each other; thus, for example, the water of *Leyden* is a lixivium of all the common-shores and jakes, which continually discharge themselves into the town-dykes: and if we consider how many tuns of dyer's-stuff are there used in the dying of wool, hair, and silk; what a quantity of alum, tartar, vitriol, aqua-fortis, and tinging ingredients, are employ'd and discharged from the dye-house-coppers, into the waters of this town; we shall find a prodigiously confused mixture thus made in the dykes that chiefly empty themselves into the lake of *Harlem*: whence it is no wonder, that many beautiful dyes should be struck to advantage at *Leyden*, which are unsuccessfully attempted by the same means in other places, even by the same workmen; as we learn from numerous experiments. This stagnant water is much more ponderous than the natural. Upon putting twelve ounces thereof into a clean glass-bason, and evaporating it with a gentle heat, numerous worms, insects, and other little creatures were found at the bottom; as also a large quantity of yellow terrestrial, calcarious matter, and mud, which raised a strong effervescence upon being mixed with aqua-fortis. The several sorts of water, being examined hydrostatically by Dr. *Hoffman* (g), with a glass water-poise, divided by lines, were found to differ considerably in weight: thus, pure rain-water was found to be the lightest; and therefore served as a standard to the rest. River-water taken from the river *Iffel*, was one line heavier than the former; the common drinking water of *Hall* was two lines heavier; the spring-water of the same place was four lines; the water of a particular spring in the same place

was

(c) *Ad. Lips. an.* 1687. p. 650.

(d) *Ibid. an.* 1683. p. 519.

(e) See *Boyle's Med. hydrof.* p. 104.

(f) See *Boyle's Usefulness of Phil.* part. 2. p. 114.

(g) See *Hoffm. Observ. chem.* p. 140.

was six lines; and some water long kept in an open vessel in a cellar, was six lines and a half: but stagnant water, taken out of the town-ditch at *Hall*, was the heaviest, being seven lines heavier than the rain-water (*b*). This shews how careful we ought to be in making experiments on water, which differs so greatly from itself; as every difference here may vary the effect: whence we should know the way of trying the purity of water, before we use it. The best trial for the purpose is, by a solution of perfectly pure silver in aqua-fortis; for this solution being diluted with the purest water, and then dropp'd into a glass of any water to be examined, if the liquor does not grow turbid, white or opaque, the water may be esteemed perfectly pure; unless it should contain good spirit of nitre, or aqua-fortis: so likewise pure oil of tartar *per deliquium*, well diluted with the purest water, and dropp'd into a glass of any water to be tried, if no cloudiness arises, it is a proof that the water is pure; for, except alcalies, this readily shews, by the sudden change of colour, whether any other substances are mixed therewith. But no experiment in this case is more exquisite, than that made by using a solution of *saccharum Saturni* in fair water; for, this being dropt into any heterogeneous water, instantly manifests its impurity (*i*). 'Tis of great use in chemistry, to have such methods of examination, where exactness is required; and where the least foreign admixture may alter the whole operation. Hence proceed the frequent failures in producing the *arbor Diane*, and the phenomena of colours by chemical liquors.

70. Upon considering all that is here discovered of water, we may say, that it is a certain species of glass, which melts with thirty-three degrees of heat, and grows hard in a little greater degree of cold, whereby it becomes a solid, elastic, brittle, pellucid, insipid, scentless mass, capable of being ground into microscopes and burning-glasses. This glass indeed is volatile, but in other respects resembles common glass. And here it is surprizing that the fluid and soft body of water should so quickly be turned into a hard solid; and that an unelastic fluid should thus become highly elastic; insomuch that if form'd of a globular figure, it will rebound like glass, or an elastic metal. This elasticity and hardness of ice increases in proportion to the degree of cold whereto it is exposed; so as in the utmost degree thereof to grow as hard as real glass, and highly elastic; but when melted, it presently becomes volatile. If, as some have pretended, a long continued extreme cold could turn water into crystal and gems, incapable of fusing at a glass-house furnace, it might thus receive fire enough to make it shine and glow, like metals, stones and other solid bodies; but as far as we hitherto know of its nature, it seems impossible, by any means whatever, to heat water above two hundred and fourteen degrees. When ice is once dissolved, it immediately becomes a menstruum, and a kind of universal vehicle, dissolving active bodies especially, mixing them together, applying them to each other, qualifying many that were corrosive, joining itself with them, agitating the whole, and thus producing the principal physical changes and operations in nature.

Ice the natural state of water.

Its physical effects.

O o o

71.

(b) See *Hoffm. obs. chem.* p. 140.

(i) See *Acad. del Cimento.* p. 237.

Conveys ali-
ment.

71. The nutrition of animals is performed by means of water; not that its particles universally constitute their substance, but without the intervention of this vehicle, the true nutritious particles could scarce be conveyed to the parts of the body, which require to be nourished; so that water alone is the proper vehicle of nutrition, without which no creature could live.

Its effects on
the body.

72. Water also makes the most mild, fluid and subtile part of the juices of the body, so as to pass thro' the minutest vessels thereof; and if deficient in a great degree, the circulation presently stops: nor is there in nature to be found, any fluid capable of supplying the want of water in the body; so that all the actions of life are owing to water, which renders the fluid fit for circulation. Upon separating water by a gentle heat, from any animal fluid, whether of a thick or dilute kind, we constantly find it makes the largest part thereof. Again, when we examine any solid part of an animal body, we find it receives all its fitness for the uses of life from water alone; for, when this is taken away, no requisite condition to life is left behind. Health itself, and the functions consequent upon it, are more owing to water than to almost any thing else: the growth of the body is carried on by water; many diseases are caused, and many are cured by water: death itself is often brought on by water, but much oftener for want of it; and successful cures are often performed by its means. That the life of vegetables, their flourishing state, their nutrition, growth, &c. are owing to water, appears from the experiments of Dr. Woodward, and Dr. Hales, as mentioned above. The fertility of the earth, we have already observed, is chiefly owing to snow and rain; and this is farther confirmed from the observations made upon the soil of *Egypt*: for, where little dew or rain falls, and no rivers water the ground, the earth is barren, like the sands, of *Lybia*, especially, where the winds frequently disturb and blow away the sand, and thus destroy the first rudiments of fertility (A).

On vegeta-
bles.

In fossils.

73. Lastly, fossils, so long as they remain, under a liquid form, in mines, and, even metals themselves, in the form of a thick, unctuous, ponderous, saline juice, are capable of dissolving in water, and indeed are naturally mixed therewith; as we learn from the writers of minerology and metallurgy, especially the excellent *Agricola*. And this holds of all concentered, saline, vitriolic and metallic juices; where water makes the principal part, and serves to dilute, move, change, increase, and mix them among one another.

Partber uses
of water.

74. Thus we see that the use of water is wonderfully universal. And farther, the principal, fine and grateful colours of bodies, are owing to water; as remarkably appears in the bright colours of flowers. So likewise the particular odours of bodies are every where chiefly mix'd, preserv'd and perfected by the interposition of water, which serves as an admirable vehicle to them. The great diversity of tastes also depends upon a proper intermixture of water, whereby sapid bodies are chiefly apply'd to the tongue and palate. The particular virtues of bodies, whether alimentary, medicinal or poisonous, are render'd active by means of water. That the hardness and firmness of bodies are owing to water, interposing as a cement, we have shewn above. Thus, if it was not for water,

the

(A) See Lord Bacon of winds.

the substance of brick, tile, stone, bone, horn, &c. would be no more than light, unconnected dust. Most of the physical actions of bodies upon one another, are principally owing to water, and could not be exerted without it: thus, the effervescences betwixt salts and salts, salts and oils, and salts and solid bodies, do not happen till the salts are dissolved by water into a fluid form; for, till they are thus dissolved, or whilst the salts remain in a solid form, they exert no action. Numerous changes and operations arise merely from such effervescences, which therefore necessarily depend upon water (1): thus likewise fermentations, which produce so many, physical changes, can by no means be performed without water, of which if vegetables be depriv'd, they can never be brought to ferment again. Putrefaction never happens in the dry bodies of animals or vegetables, and in this state may long be kept uncorrupted in a dry air, but if once moistened with water, they soon putrefy and corrupt. There are also numerous separations of different bodies, that cannot be made without water, but easily by means thereof: thus, salts are easily separated from earth, and oils and alcohol from resins, by water. On the other hand, an intimate union is in many cases procured by water, and could not be brought about without it; of which we have given numerous instances above. Precipitation, which is a capital operation in chemistry, chiefly depends upon water; so does the distillation of all the aromatic oils, and cannot be obtain'd without it in purity and perfection. Water also serves us to measure the degrees of heat, from thirty-two degrees up to two hundred and twelve; which is very difficult to do by any other means: oil, indeed, might serve for this purpose, and go even to six hundred degrees; but then oil continually grows thicker by fire, and does not afterwards rise equably in proportion to the heat; whereas water constantly remains the same in this case. This is a thing of primary use in chemistry, and unknown to the ancient chemists, who would not otherwise have been so anxious about finding a method of raising and keeping up an equable degree of heat, like that of a hen brooding upon her eggs; which heat may now easily be continued by means of water and a thermometer. But here we are to observe, with respect to all the effects of water above-mentioned, that they constantly differ according to the different degrees of fire apply'd; which needs no farther confirmation.

75. Water has never been found more active and powerful, than when raised by a boiling heat into vapour, and confined in a close place; for, bodies expos'd to this vapour, so as to be thoroughly moistened thereby, are

The hot vapour of water, powerful.

(1) An experienced German chemist relates, that in some parts of his country, he met with vitriol stones, or marcasites, which, by the action of mere common water, resting for a competent time upon them, would grow so hot, as to enable the liquor to retain a sensible heat, when it had passed a pretty way from them. And many accidents may occasion the breaking out of such waters, or the change of their course in subterranean places. That common water may, in a very short time, produce considerable heat in mineral bodies, appears by mixing two or three pounds of fine powder of common brimstone, with a convenient quantity of filings of iron; for this mixture, being drenched with common water, will, in a short time, grow exceedingly hot, and send out a thick smoke, like that of good quicklime, while slaking with water.

thence many ways wonderfully penetrated, corrupted, altered and dissolved. Experiments purposely made have shown, that the vapours of salt-water, raised by a gentle heat, are less putrefactive to the bodies exposed thereto, than the vapour of fresh-water, which corrupts them sooner and more thoroughly: whence we see, that the vapour of fresh-water is more putrefactive than of salt-water; and that the ancient physicians justly observed a moist and hot air, growing pestilential, would in a short time dissolve the human body. And it was found, that when the *Europeans* first settled in *America*, almost all of them died of a malignant distemper, or a kind of fever peculiar to the place, which soon putrefy'd and dissolved their bodies; and this principally happened to those, who inhabited the wood-lands, where the air was wet, with the copious, warm vapours, which perpetually exhaled from the trees. For, according to Dr. *Hales's* calculation, given in his *Vegetable Statics*, of the proportion of water perspir'd from the surface of the leaves of a tree in summer, a most prodigious quantity must needs be exhaled from a large wood, in a hot climate: but when these woods in *America* were cut down and burnt, and the air suffer'd to have free admission, the country soon became wholesome (m).

Ice, whence
lighter than
water.

76 *Galileo* was the first that observed ice to be lighter than the water which compos'd it: and hence it happens, that ice floats upon water; the specific gravity of ice being to that of water as eight to nine (n). This rarification of ice is owing to the air-bubbles produced in the water upon freezing; and, being considerably large in proportion to the water frozen, render the body of ice so much specifically lighter. We have shown in the history of air, and in the present chapter, that a considerable quantity of air is lodg'd in the interstices of water, though it has not then any elastic property, on account of the disunion of its particles: but these particles, coming closer together, and uniting as the water freezes; light, elastic and expansive air-bubbles are thus generated, and increase in bulk, as the cold grows stronger; whence, of course the ice becomes specifically lighter: and these air-bubbles, growing larger, acquire a great expansive force, so as to burst the containing vessel, though ever so strong. It has been imagin'd, that this bursting of the vessels by frozen water, was owing to the contraction of the solid parts of the vessel upon the ice, and not to the internal expansion; but the *Florentine* academicians show'd the contrary by the following experiment. They fill'd a hollow globe of pure gold with cold water, then soldering up the orifice, expos'd it to a freezing air; having first fitted on to it a metallic ring, somewhat less than a great circle of the sphere, and carefully mark'd the part of the sphere, where the edge of the ring touch'd it. Whilst now the water froze in the globe, they observ'd the external surface to be so much enlarg'd, that the metallic ring remarkably ascend'd towards the vertex from the greatest horizontal circle: whence the globe expanded much more than the ring contracted, by

Bursts vessels
in freezing.

(m) See *Art. Liff. suppl.* III. p. 167

(n) See *Exp. Acad. del Ciment.* 25. 32.

by the cold; as was plain upon comparing this ring with another originally made of the same size (o).

77. But snow-water, or any water long boiled at the fire, freezes slower, *ice from water exhausted* and affords a more solid ice, with fewer bubbles, than other water not so treated (p). And pure water long kept *in vacuo* and froze afterwards there, *of air.* freezes much sooner with the same degree of cold, than water unpurg'd of air, and expos'd to the atmosphere; whilst the ice, thus made of water from which the air was extracted, is much harder, more ponderous, equable, and transparent, than common ice. Whence it is certain, that the air, naturally contain'd in water, being brought together by the freezing cold, occasions its greater rarification and levity: and in this manner ice has been procured, that would not float upon water (q). If finely powder'd sea-salt, sal-gem, or sal-ammoniac, be but to powder'd ice, or snow, in a freezing season, and they be well mixt together, the salt will immediately begin to dissolve, and the coldness grow much more intense; and this, so far as we yet know, to a certain degree, whatever were the degree of cold in the bodies before their mixture. Alcohol also, being thus mix'd with ice, increases its coldness: the pure, saline, acid spirits of sea-salt, nitre, aqua-fortis and aqua-regia, the stronger they are, the more intense cold they produce, when mix'd with ice; but of this we have already treated sufficiently in the chapter of fire.

78. Hence, to make the most perfect ice, we should take the purest water, *The most perfect ice.* and perfectly purge it of air by the air-pump, then freeze it in the severest frost, by means of *Fabrenheit's* contrivance; for thus we should obtain an ice of the greatest hardness, density, purity, transparency, and gravity; the true physical characters of ice to the senses: though even this ice, so far as we now know, would immediately melt into water with a heat of 30 degrees. Whence it follows, that the utmost natural cold cannot convert pure water into stone, crystal, or gems; for this artificial cold is above

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(o) There are other ways to manifest this expansion of water by freezing: Mr. *Boyle* having poured a proper quantity of water into a strong cylindrical earthen vessel, he exposed it, uncovered, both to the open air in frosty nights, and the operation of snow and salt; and found that the ice produced in both cases, reached higher than the water before it was froze.

So if a concave cylinder, made of any compact matter, be tightly stopped at one end with wax, and filled with water at the other, and then that also be closed in the same manner; if this pipe be suspended in an air sufficiently cold, the contained water will be froze, and the stopples at both ends, or at least at one, will be thrown out; and a rod of ice appear thereat, in continuation with the tube.

A stone-cutter complained to Mr. *Boyle*, that sometimes, thro' the negligence of the servants, the rain being suffered to soak into marble, the violent frosts coming on would burst the stones. And another tradesman complained, that even implements of bell-metal, being

carelessly exposed to the wet, have been broken and spoiled by the water; which having entred at the little cavities of the metal, was there afterwards froze, and expanded into ice. And *Cabeus* tells us, that he saw a huge vessel, of exceeding hard metal, split asunder by congealed water.

Busbequius relates, 'That at *Constantinople*, a monstrous obelisk, thrown from its pedestal in the city, had remained at its length for many ages; till in latter times an architect appeared, who for a certain sum undertook to set it again upon its base; and having to this end prepared abundance of machines, he therewith raised it within an inch of its due height; then throwing water on the ropes that supported the pillar, they gradually contracted, and set it upon its base.' To render this the more credible, the like is mentioned by many eminent authors, as having been elsewhere practised; and the thing is allowed off by *Galileo*.

(p) *Acad. del. Cimento*, p. 163.

(q) *Ibid.* p. 171.

40 degrees stronger than that, where water is said to be frozen into rock-crystal. In our experiments, no increase of cold has made ice at all more difficult to melt than common ice.

Containing
something more
subtile than
air.

79. When water is perfectly purg'd of air by the air-pump, and shook in the containing vessel, it discharges an infinite number of little bubbles, that dart from it like sparks of fire, and have no appearance of air; these, therefore, may possibly form those explosive unaerial bubbles, which arise from water long kept boiling over the fire, after the air seems all to have been discharged (r).

Often wonder-
fully con-
cealed.

80. Nothing seems more capable of deceiving us than water: thus, in the air, the parts of water, being dispos'd after a certain manner, may form dense clouds; whereas the same water may be there collected in a greater quantity, and degree of density, yet being barely dispos'd in a different manner, it may be so pellucid as not to appear to the eye. The breadth, forcibly discharg'd from the mouth, when the lips are contracted, is scarce visible; but when gently let go, with the mouth wide open, and meeting with a cold air, it forms a visible cloud. In summer, the moist breath does not appear to the eye; but in the winter it appears like a mist. Hence chemists are to be admonished to use hygrometers, whereby they may determine the quantity of water in the air at any time: which is a thing of consequence to them; as may appear from the necessity of knowing the best time for preparing *oleum tartari per deliquium*, and *oleum sulphuris per campanam*.

The waves of
water.

81. When water stands perfectly still, its surface is parallel, or concentric, with that of the earth; but if any heavy body falls into this stagnant water, it drives a bulk of water along the surface, equal to the bulk of the body thrown in: and this expulsion of the water continues successively, so long as any of the body continues above the surface of the water; afterwards the body descends equally without being perceived; whilst the water, raised by the falling body out of its place, immediately slides into it again, as soon as the body deserts it: whence an undulatory circle is made upon the surface of the water; which circle is propagated from the place where the body fell, as from a centre, and widens into larger and larger concentric waves, whose diameter increases constantly 12 feet in 8 seconds and a half; whereas sounds in the air move at the rate of 1080 feet in a second: whence the motion of a wave of the air, is to the motion of a wave of water nearly in the same proportion as the weight of water to the weight of air, according to the calculation of *M. de la Hire*. These waves, though proceeding from different causes, and even intersecting each other, still continue circular, and each of them concentric to its own centre; and if, in their progress, they meet with any obstacle, whereby they are resisted or reflected, they still go on, with the same velocity, as if they had not been obstructed: nay, what seems stranger still, tho' the wind be with them or against them, it does not hinder their moving in the same manner (s).

82. When

(r) See *Du Hamel, Demonstr.* p. 395.

(s) See *Memoir. de Phys.* an. 1693. p. 133.

82: When pure water is, with a gentle heat, distilled to perfect dryness, in a clean retort, it leaves a light spot, or film, at the bottom of the glass, and this every time the same water is redistill'd in a fresh vessel; and if the same retort be used in redistilling the water, the spot or crust will grow a little larger upon every distillation. This experiment has been industriously prosecuted; inasmuch that Mr. Boyle (1) relates, that water being carefully distilled in a glass-vessel, 200 times over, an ounce thereof at length afforded six drams of a white, light, insipid, fix'd, ponderous earth, undissolvable in water (u). Hence, many relying upon his authority, have asserted, that water, barely by repeated distillation, might be converted into true earth. And hence Sir Isaac Newton infers, that water thus chang'd into earth, may be ignited (x). On this occasion, therefore, I beg leave to relate the success of my own experiments upon the subject. Having collected a quantity of rain-water, in clean open vessels, placed on the top of the observatory at Leyden, so that no foul water might fall into them from the building, I afterwards distill'd, to perfect dryness, a large parcel of this water, from a glass retort, into a pure receiver, by means of the gentle heat of an athanor, to avoid smoke; and found, at the bottom of the retort, a white spot, extremely thin and small with respect to the water; whilst a considerable proportion of the water was lost in the operation, tho' I carefully secur'd the juncture of the vessels with a luting made of linseed-meal and water. Whence I cannot conceive, how it is possible, by any care, to prevent water from escaping thro' the luting, before it could be distill'd 200 times over. In repeating my distillations, I could not but reflect, that the part of the vessels, unpossess'd by the water, was fill'd with the common air of the laboratory; and that this air must needs be full of dust, rais'd by the motion of the fire, currents of air, &c. as we see the surfaces of glasses in a laboratory are usually thick cover'd with dust. Whence I doubt not, that in each distillation, fresh dust is added to the former; for if the same water be distill'd 200 times over, and always return'd back into the same vessel, all the dust floating in the air of these

Whether water be convertible into earth.

(1) This instance of the convertibility of water into earth, is so considerable, that it may deserve to be delivered more at large: The author relates, 'That having put a considerable quantity of distilled rain-water into a clean glass body, and fitted it with a head and receiver, he suffered it to stand in a digressive furnace, till by the gentle heat thereof, the water was totally abstracted, and the vessel left dry; when being taken out of the sand, he found the bottom of the glass wholly covered with a whitish substance; which being scraped off with a knife, appeared to be a fine earth, without any manifest taste—This encouraged him to distil the rain water again, in the same glass body; at the bottom whereof, when the water was all drawn off, lay more of the like earth, which confirmed his conjecture, that the earthy powder might be a transmutation of

' some parts of the water into that substance. Herein he was farther encouraged by a physician, who assured him, that he had frequently found such white earth in rainwater, after distilling the same many times successively; adding, that he found no cause to suspect, that if he had continued to re-distil the same portion of water, it would have yielded him more earth. Lastly, a very ingenious person, who had tried various experiments on rain-water, put him beyond all doubt about this transmutation: for he solemnly affirmed, on experience, that rain-water, even after distillation in very clean glasses, near two hundred times, afforded him this white earth; and that more conspicuously in the latter distillations than in the former.' Boyle of Forms and Qualities.
(u) See Boyle, *Origin of Forms*, p. 259—237.
(x) See Newton, *optic. Latine*, p. 319.

these vessels must thus be collected 400 times, on account of the water's being pour'd backward and forward in the open air. And tho' in this case, some of the powder may be owing to the feculency of the water; yet the greatest part, doubtless, proceeds from the air. If we calculate, from experiments, the proportion of each of these powders, it does not appear certain, that the earth, obtain'd in this operation, proceeds from the true elementary substance of water: and my suspicion is here the stronger, as I find Mr. Boyle repeated the experiment only thrice himself; and had it from another chemical hand, that an ounce of water, distill'd 200 times over, afford six drams of earth. That water may concrete, along with other substances, into a true solid body, we have seen above; but that it may, without the interposition of any thing else, be by distillation converted into true earth, has not hitherto been shewn by sufficient experience. I have learnt, by numerous examples, how apt men are to overlook things that mix themselves unexpectedly in chemical operations. And thus I finish all that I can justly say, from our present natural philosophy, upon this third universal instrument of chemistry.



Of EARTH.

1. **B**OTH philosophers and chemists use the word earth for a principle, or element, in the composition of bodies, entering them either as an ingredient, or giving them a power of performing various operations in nature and art. The word properly denotes a fossile, simple, hard, brittle body, that remains fix'd, without melting, in the fire; and neither dissolves in water, alcohol, oil, or air (a). Earth defined.

2. It is a body, as having three dimensions, impenetrability, figurability, and its own particular gravity. I judge it of the fossile kind; for, it is mixt almost with every fossile, either in a greater or less proportion; tho' it is hard to shew it in metals. In weight it exceeds water, salts, and the spirits of vegetables and animals. It every where insinuates itself into the bowels of the earth, where it is constantly found, and may be dug up: but when pure, it seems homogeneous, or unmix'd with other elements; whence we can refer it to no tribe of bodies so properly, as the fossile. When pure, or perfectly separated from other bodies, it is consistent, hard, and fine, tho' brittle with regard to our senses, and easily reducible by trituration into a certain powder; in which respect it greatly differs from the true metals and gems; tho' still more in this, that it remains fix'd and unchang'd in the most violent fire; even so far, as when pure, not to flow therein. Explained.

3. The dry remainder, left upon the careful distillation of rain-water, being collected, thoroughly calcin'd and elixated, affords a pure subtile, virgin-earth; which seems to proceed from the dust of the air (b) as mentioned at the end of the preceding chapter; for the dust floating in the air seems to be principally Virgin earth obtained from water.

(a) The doctrine of elementary earth here delivered, appears greatly to countenance Sir Isaac Newton's notion of the original formation of matter; by shewing that an unalterable solid substance has an existence in nature. This great philosopher is pleased to tell us, it seems to him, 'That God in the beginning formed matter into solid, massy, hard, impenetrable, moveable particles, of such sizes and figures, and with such other properties, and in such proportion to space, as most conduced to the end for which he formed them; and that these primitive particles, being solids, are incomparably harder than any other bodies compounded of them; even so hard as never to wear, or break in pieces; no ordinary power being able to divide what God himself made one in the first creation. While these particles, says he, continue entire, they may compose bodies of one and the same nature and texture in all ages: but should they wear away or break in pieces, the nature of

things depending on them would be changed. Water and earth composed of old, worn-out particles, and fragments of particles, would not be of the same nature and texture now, with water and earth, composed of entire particles in the beginning. And therefore, that nature may be lasting, the changes of corporeal things are to be placed only in the various separations, and new associations and motions of these permanent particles; compound bodies being apt to break, not in the midst of solid particles, but where these particles are laid together, and only touch in a few points.' Newton's Opt. p. 375, & seq.

(b) Mr Boyle, in his curious treatise of Effluvia, observes, that earthy matter may be raised in a very considerable quantity into the air; and to this purpose relates from Agricola, an account of a shower of rain, which covered the streets it fell upon, with clay.

principally earth, attenuated by numerous causes, so as to fit it for being suspended in the air, and moved about therein, by the winds: whence it mixes itself intimately with dew, mists, clouds, rain, snow, hail, &c. And although the earth, thus obtain'd from the distillation of rain-water, be so fix'd in the fire, that, as Mr. Boyle found, it would endure the utmost violence thereof, without changing or flying off; yet this property does not contradict its being volatile, so as to float a subtle powder in the air: for it is one thing to remain fix'd in a violent fire; and another, to be carried away with the motion of the air or wind. Thus, if fine powder'd earth be put into a crucible, and cover'd on all sides with fire, it thus may rest unmoved; whereas, if blown upon by bellows, so fine a powder would immediately be dissipated. And thus, as clouds of water are carried about by the wind, so are clouds of sand in *Egypt* and *Lybia*; tho' sand be a fix'd thing in the fire. Here also it should be consider'd, that bodies purely terrestrial may remain fix'd in the fire; but, when mix'd with others, become so moveable, as to be rais'd into the air by a gentle heat. Thus, pure gold is extremely fix'd in the fire; but if first mix'd with regulus of antimony, then well ground with mercury-sublimate, it is so chang'd, as to fly into the air with a gentle fire: in like manner, pure earth, when separated from all other things, endures the most violent fire unmov'd: but, when mix'd with other bodies, a moderate heat may carry it off; as we see in wood burnt upon a hearth: where the smoke rises to the top of the chimney, and there turns to soot; which, when chemically treated, affords a large proportion of earth, here rais'd to the top of the chimney, by being mix'd with an oil and salt; tho' the earth itself, when purified, cannot be thus rais'd by any violence of fire. Hence, therefore, we have one way of procuring pure earth, by the distillation of pure water (c); tho' the earth, thus obtain'd, will contain whatever floated in the air along with it, unless this be so light as to rise with the degree of heat employ'd in the distillation.

From calcined
vegetables.

4. Vegetables, by being burnt in an open fire, fall into white, fix'd, subtle ashes, that are easily blown away with any wind. Every plant is capable of affording these ashes; which being perfectly elixated with rain-water, so as to take up all their fix'd salt, after the open fire had totally consum'd the oil and volatile salt of the subject, nothing but earthy matter will remain behind, along with the water; so that these two being now shook together, and perfectly wash'd, by the repeated affusion of fresh water, from all stony, sandy, and other solid particles, that will not be suspended in water; and the several turbid washings being afterwards suffer'd to rest together, till all that will fall to the bottom be deposited; if the clear water be then decanted.

(c) The great quantity of earth which Mr. Boyle obtained in proportion to the water distilled, with the probability there is, that if the operation was often enough repeated, the whole body of the water would be thus converted into earth, renders it impossible with some to suppose the phenomenon entirely owing to the causes some have imagined. The fact, say they, is much better accounted

for by the excellent author himself, from the known and allowed effects of fire or fœcul, which has the power of making new coalitions of particles in bodies, and thence of introducing new forms: and thus alcohol of wine may be reduced to earth, as well as simple water, according to Mr. Boyle. See his *producibleness of chymical principles under the article Earth*.

ed, we shall find at the bottom a fine earthy substance; which, when dry'd, by a gentle fire, is elementary earth, chemically obtain'd from vegetables. This earth is perfectly insipid, scentless, white, soft, and but little elastic; it neither dissolves in the air, in water, in the fire, or in oil; it also remains fix'd in the fire, and of itself not convertible into glass; with water it mixes into a kind of paste, whereof tests and muffles may be made for the refining of gold and silver, and the trying of ores: for, this earth will long sustain the force of melted lead in a violent fire, without vitrifying or cracking; but suffering all imperfect bodies to pass thro' its pores, or vitrify with lead. And by these marks we may know the nature of pure earth, chemically obtain'd from the ashes of vegetables.

5. The same kind of earth is also obtain'd from that part of vegetables, *From smoke and foot.* which in burning flies off in the form of flame, sparks, smoke, or foot; and this, whatever the vegetable be, whether recent or long kept, sharp or mild: for if foot, taken from the top of a chimney, be calcin'd in an iron-pan, it smokes, ignites, takes flame, and at length falls into white ashes; which, when well elixated, afford an earth in all respects like the former. Hence we understand, that earth may be render'd very volatile, when agitated by a violent flame, whilst mix'd with volatile substances; and that it may thus be carried to a great height, diffus'd thro' the air, and mix'd therewith: so that when black smoke arises from burnt vegetables, in the form of clouds, earth itself, here made volatile, appears with the rest under this form. So again, when foot is distilled in a glass-retort, with different degrees of fire, it affords water, spirit, volatile salt, and different oils; leaving behind a black matter, which, when burnt in an open fire, and elixated with water, affords the same kind of earth as in the foregoing experiments. This shews us, that the force of fire is able to raise even earth itself, along with water, oil and salt; and that the earth, so rais'd, is of the same nature with that obtained from the fix'd ashes of plants after burning: which shews us an unexpected property of earth; for the earth, which was so volatile in burning as to rise in smoke or foot, yet after it comes to be separated by distillation, or calcination, from all aqueous, oily and saline particles, it then proves as fix'd as the earth of the vegetable, remaining in the fix'd ashes after burning. And hence, earth, when alone, is fix'd in the fire; but if intimately mix'd with oils and salts, it is by their means easily volatiliz'd. This shews us, how full the air must be of a true earthy matter; especially in those places where vegetables are continually burnt.

6. All the known vegetables, if distill'd by the retort, with the several *By distillation.* degrees of fire up to the last, are thus separated into two different parts, the one being rais'd by the force of fire, and carried into the receiver; whilst the other cannot be so rais'd, but remains behind at the bottom of the retort, in the form of a black, fix'd coal, not to be farther chang'd by this means, as *Helmont* related, and *Dr. Hooke* shew'd by experiment. It is commonly supposed by chemists, that water, spirits, oils, and volatile salts, rise as volatile parts into the receiver, under the form of liquors; whilst the earth, the fix'd salt, and a little fix'd oil remain behind at the bottom of the retort. The truth is, the first volatile part in this operation differs from itself, as consist-

ing of water, spirit, acid salt, alkaline salt, and different oils; which, when all mixed together, constitute a substance like that of smoke or soot, but with this difference, that when these principles are rais'd by an open fire, they ascend more copiously, and in a grosser form, than when distill'd in a close vessel. Whence an equal quantity of the same vegetable subject affords much less ashes, upon being burnt in an open fire; as a much larger proportion of coal and ashes remains in the retort after distillation: but if all that pass'd into the receiver, in the operation, be again distill'd to dryness, a black, fix'd coal will thus constantly remain at the bottom of the vessel; and can never be render'd volatile by the most long-continued violent fire; tho' smoke indeed will be thus rais'd from it. If the remaining light and spongy coal be at length taken out, and calcin'd in a clean vessel in a naked fire, it will burn, take flame, lose all its blackness, and leave a white substance; which, when duly elixated, will prove the same virgin-earth as above-mentioned: whence again it is plain, that this earth rises along with water, salts, spirits and oils, in the distillation of vegetables. If the oil, obtain'd in this distillation, be in the same manner distilled with all the degrees of fire, a much purer and more penetrating oil will come over into the receiver: and by repeating the operation several times, an oil may be thus obtain'd so thin and subtile, as to resemble alcohol; but then a large part will at each distillation vanish into the air; and the peculiar spirit, which gave the smell and taste to the oil, be totally lost; whilst every time, a black coal constantly remains at the bottom of the receiver, and can never be made volatile, not to afford any salt; tho' when burnt in an open fire, it yields white ashes, and a considerable proportion of true elementary earth: and how often soever the oil be thus distill'd over, it deposits earth every time; so that at length the principal part of the oil may, by this means, be converted into pure, simple earth, as appears from the experiments of Mr. Boyle (d).

7. Hence it appears, that the same earth is producible from all the parts of vegetables; the senses not being able to perceive the least difference in different parcels of earth, thus procur'd: and all this earth, if perfectly pure, is so fix'd in the fire, as scarce to suffer the least change by the utmost violence thereof; yet, when mix'd with other volatile parts of vegetables, it then becomes volatile in the fire, whether apply'd in the way of open calcination, or close distillation. Again, we see that no volatile part of a vegetable renders earth more highly or more easily volatile than oil; but among the various kinds of oil, which nature or art produces from vegetables, there is none that carries off more earth than that gross pitchy sort which rises last, in distillation, with the highest degree of fire. Whence the superior weight, thickness and tenacity of this oil, seem owing to the greater quantity of earth it contains: and accordingly, if depriv'd of its earth by distillation, this oil becomes proportionably thinner, lighter, and more volatile.

8. The better to understand the nature of this earth, it is proper to consider the fix'd alkaline, saline part of the ashes, obtain'd by the calcination of vegetables; which saline part is wash'd away from them, by the water used in their elixation. One might be apt to suspect, that no earth would remain

*Earth in fix'd
alkali.*

(d) See Boyle, *Script. Chym. passim.*

remain in this salt; as it is manifest, that earth was left undissolved by the water, which dissolv'd the salt, and carry'd it thro' the filtre in purifying the lixivium, after the terrestrial fæces were by long rest fallen to the bottom, and that the solution pass'd thro' the filtre as limpid as water; in which state this liquor being examin'd, even by the microscope, no signs of an earthy matter will appear therein; and if kept for years in a vessel perfectly clos'd, it deposits nothing terrestrial: yet if this pure lixivium be put into a clean glass, and set in a quiet place, where no dust can come, till it acquires the consistence of oil; and this thick liquor be afterwards boil'd in an iron-pan to perfect dryness, it leaves a pure fix'd alkaline salt at the bottom; which being melted in a strong fire, then pour'd into a brass mortar, and reduc'd to powder, and afterwards suffer'd to run *per deliquium*, there will be found at the bottom of the containing glass a white, earthy powder; which, when wash'd from all the adhering salt, proves to be perfect earth, like that obtain'd from vegetable ashes. And if the liquor, thus obtain'd, be again evaporated, and the salt again calcin'd and run *per deliquium*, it thus also deposits more earth; and by repeating the operation, a very large part of the fixed alkaline salt may thus be turn'd into pure simple earth, which in the burning was so united with the saline principle, as to give it the form of an alkaline salt; whilst that saline principle, by repeated calcination and solution in the open air, separates itself, flies off into the air, and leaves only the earth behind. If all this earth be carefully collected and weigh'd, it will be found much lighter than the salt employ'd; which shows that a large part of the salt is thus render'd volatile, and flies off.

9. As this experiment is always made with the same success, we may learn from it, that earth was contained in the fix'd alkaline salt, from which it is thus procur'd; tho' it before lay so conceal'd therein, as to be perfectly dissolvable in water, a property otherwise repugnant to the nature of earth. Hence also it appears, that pure earth, when united to another principle, may be perfectly dissolv'd in water, tho' not at all, when it exists separate; unless we should here suppose, that the salt by this repeated calcination and solution is actually converted into earth. But this supposition, so far as I know, is confirm'd by no argument or experiment and therefore passes with me for a supposition, contrary to the constant course of nature, which always acts in the same way, and by the same means: for, it has never hitherto appear'd, that one element prevails over another; but that they all preserve their respective proportion, or assign'd balance among themselves, from their first creation to the present time. On the other hand we learn from numerous examples in chemistry, that when earth is united with other saline principles, it may thus be dissolved by water into a liquor, where no terrestrial matter appears: so for instance, in glass, the earth united to the alkaline salt forms a pellucid mass, which yet, according to *Helmont*, may again be resolv'd into alkali and earth. So likewise, all the metals, dissolv'd by their proper menstruums, appear pellucid; tho' the metals may severally be recover'd from them, opaque, entire and unchanged. Thus again, chalk, stones, shells, earths, &c. by means of saline liquors seem convertible into pure salts; tho' these solutions may by various means be
again

again resolv'd into their solvent liquors and earthy substances respectively, as we see in the business of precipitation.

10. We may learn from the preceding experiments, (1.) That fix'd alkaline salts, obtained from vegetables by calcination, owe their chiefest part to true elementary earth, which contributes to compose them. (2.) That this earth is so conceal'd, mix'd or united in these salts, whilst they remain alkaline and fix'd, as to be discoverable by no sign; and thus even dissolve with water, or a moist air, into a pellucid liquor. (3.) That this earth of vegetables can only be thus attenuated by the extreme violence of a calcining fire; which thus in the open air intimately unites the earth, so subtilized, along with the other alkaline, saline principle, that from the two, so join'd, fixed alkali arises, as a creature of the fire. For charcoal, closely confin'd in an iron vessel, and long detained in a violent heat, still remains a black coal, that holds no alkaline salt; but when expos'd to an open fire, it presently turns to ashes that contain a fix'd salt: which shews, that this salt did not pre-exist in the vegetable, but is produced by the fire, uniting the earth to the other concurring part, in the open air, and not in a close vessel. And it plainly appears, that this fixed alkaline salt is merely produc'd by the force of fire in the open air; because if any vegetable whatever, be only burnt to a black coal, either in a close vessel, or in the open air, this black coal, ground to powder, and boiled in water, communicates no fix'd alkaline to the water; but when once reduc'd to white ashes by an open fire, these ashes yield a true alkaline salt, by being boil'd in water. Hence, therefore, the earth of vegetables being attenuated, by the utmost violence of an open fire, whereby the oil is consum'd, and uniting intimately with the other part, is what constitutes fix'd alkaline salts; nor do I know any other origin thereof. (4.) Fix'd alkaline salts, therefore, are not simple substances, but compounded of two different principles intimately united. (5.) It is very probable, that the burning of vegetables first attenuates, then combines this earth with the native salt naturally contain'd in plants, and which usually exists in them under a saponaceous form, or a mixture of oil and salt; so that the fire, first mixing these together, afterwards consumes the largest part of the oil, and thus converts the salt, the earth and the remaining gross, black oil, into a black coal; wherein the saline part is so cover'd and defended by the oil and earth, that water cannot dissolve the salt, till a stronger fire, coming to be longer apply'd, consumes all the black oil, which serv'd as a cement to the earth and salt; whereby, the saline part, of itself considerably volatile, now seems to be fix'd, and concreted with the subtle earth: after the same manner as fix'd alkaline salt, long detain'd in the most violent fire, at length becomes volatile and flies off; but if mix'd with a certain proportion of earth or ashes, turns to glass, which long remains considerably fix'd in the fire. (6.) Hence there is no simple salt of a fix'd nature in vegetables, but its fixedness is totally owing to the earth melted into it by the fire; for, if vegetables are long kept dry, or expos'd to the changes of the air, or if perfectly putrefy'd, they leave no fix'd salt in their ashes. (7.) And hence, these fix'd alkaline salts, thus produc'd, are again resolvable into their two principles, by the means abovementioned: viz. into

a pure, simple, volatile, imperceptible salt, and a pure subtile indolent fix'd earth. (8.) Hence it seems much more probable, that these fix'd salts should be produc'd from earth and salt, in the manner just mention'd, than from the intimate union of earth and water: for in what manner soever water is apply'd to pure earth, in chemical operations, a fix'd alkaline salt is never found to arise therefrom; tho' the fire apply'd be ever so strong. (9.) This earth is obtain'd always the same, and in a large quantity, from water, spirits, volatile salts, fix'd salts, and oils, when chemically treated in a proper manner for the purpose: whilst all of them, if perfectly freed from earth, are so attenuated and volatilized, as to escape the notice of the senses, and fly off into that universal receptacle, the atmosphere; scarce any vessels being able to detain any of them except water and solid earth. Whence the ancient chemists properly said, that spirits are held down, or kept from flying away, by oils or sulphur; that earth was the only thing, which could detain sulphur and salts; and consequently, that earth was the cause of fixedness. Upon the whole it appears, that this earth is the same in all vegetables, and perhaps, an unchangeable principle.

11. We next proceed to enquire into the earth of animals. It has ever been observed that all kinds of animals, expos'd to a warm moist air, presently putrefy after death, even in a less degree of heat than that of the body in health; and, by this putrefaction they are in a short time so chang'd, that their entire bodies resolve into a fetid substance, which flies off so copiously into the air, as to leave only a very small solid portion behind. Thus the bodies of whales, elephants, camels, horses, men, &c. are soon consum'd to the bones, and vanish into the atmosphere: for, thus the water, the spirit, the oil, and salt of the subjects, evaporate in time, leaving nothing behind but a small quantity of simple, indolent, terrestrial matter, like the virgin-earth obtained from rain and vegetables, in the manner above-mention'd. Thus, we find in the church-yards of populous cities, the carcases that are there buried, turn to so little earth, as scarce raises the ground higher. Hence we see, that both the fluid and solid parts of animals are so volatile, as totally to exhale by the bare action of the air; whilst only their earthy part remains fix'd, and does not fly off with the rest: which earthy part, when closely examined, appears to be only the crumbly substance of the bones, or light ashes, easily dispersed by a gentle wind.

*Earth from
putresc'd ani-
mals.*

12. Let us proceed to trace this earth in animals, where we shall find that their juices, when converted into a true animal nature, and distill'd in clean, well-closed vessels, with successive degrees of fire up to the highest, will first, with the heat of two hundred and twelve degrees, afford an incredible proportion of water; which in most respects resembles that obtain'd from vegetables. In the same manner, with the next degree of heat, after all the water is expell'd, and the mass grown dry and scorched, there comes over a light, yellow liquor, less volatile than the water, and called by the name of spirit; having a strong smell; and being so saline, as to raise an effervescence with acids: this spirit, being again distill'd by itself, affords some faeces, which, when calcin'd and purify'd, yield a little fixed earth, perfectly of the same nature with the former. Whence it is plain, that earth ascends

*From distill'd
animal fluids.*

ascends with this spirit, and may be obtain'd from it. If the fire be now increas'd, the remaining matter affords the distill'd animal oils in a considerable quantity; which, being again distill'd by themselves, leave a copious fixed earth at the bottom, like the distill'd vegetable oils above-mention'd: whence we see, these animal oils also are convertible into earth by a repeated distillation, till at length they remain of a subtile and almost spirituous nature; being thus freed from their earth, which gave them their grossness, tenacity, and fixedness. The volatile salt, which here rises, in part, together with the oils, and in part, separately, after them, always at first holds a copious oil, intimately mix'd, which by its viscosity fixes, detains, and binds down the salt: for, as soon as all oil, is by the proper operation perfectly separated, this salt immediately becomes totally volatile, and leaves no fæces behind it upon repeated distillation: tho' it always leaves an indolent water at the bottom, after being sublim'd by a soft fire; for, this water adheres so to the salt, tho' in appearance ever so dry, as to manifest itself by remaining behind upon a gentle sublimation: nor can this water, scarce by any other means, be so far separated from the salt. Whence all the fixedness, which we find in native animal salts, seems wholly owing to native animal oil, whereby they are detained; whilst this oil itself owes all its fixedness and tenacity to the earth combined therewith: this earth being the true cement, that binds down the animal salt, which would otherwise be too volatile. When by the violence of the fire, the former oils are driven over; there arises another, of a black, gross, clammy, pitchy nature, which often fills the whole neck of the retort, and comes into the receiver, like rarify'd pitch. This oil is more ponderous than all the liquors that came over before; and upon being redistilled, leaves a copious earth in the retort, though urged with ever so violent a fire: and if the distillation be often repeated, the oil becomes every time more liquid, and constantly leaves a large proportion of earth behind. Thus upon re-distilling several pounds of the fetid oil of hartshorn, in order to rectify it; after many repeated operations, I obtained a thin, pellucid, volatile oil; and a large quantity of black, unctuous, terrestrial substance; which being burnt, with an open fire, afforded pure earth: whence I was convinced, that this last gross oil, tenaciously adhering to the earth, is made to rise therewith by a violent fire; so, tho' this substance be called oil, yet a large part thereof is mere earth, that may be volatilized with oil, by a strong heat; whilst the peculiar properties of such oils depend little upon the true oil itself, but chiefly upon earth, and the great degree of heat required to raise them: for, hence proceeds their superior fixedness, tenacity, and weight; of all which they are deprived, when well purged of their earth. Whence again, we understand that earth is intimately, and almost inseparably mixed with all animal oils; and that this admixture constantly hinders their volatility: for as oils volatilize earth in the fire; so earth mixed with oils, always lessens their volatility; and, as volatile spirits are rendered less volatile by oil; so volatile oils are rendered more fixed by earth. If the black fixed substance, that now remains behind in the retort, be for a long time urged with the utmost degree of heat, thick, shining, blue fumes will

will at length arise, together with little fiery sparks; which, being received into cold water, are there condensed, and falling to the bottom, from little masses, called by the name of solid phosphorus; as the former, coming over in fumes, might be called liquid. This phosphorus, if exposed to the air, burns with a bright flame, consumes and flies away with a particular stench; leaving a thick, acid, and somewhat terrestrial water behind it. Whether this phosphorus be a production of the fire, or of an animal, or vegetable substance, or of all three together, may be questioned; but if we consider, that it burns in the air, never dissolves in water, and melts like wax, with heat, at the bottom of water; it should seem to be rather of an oily, than of a saline, or earthy nature: though it greatly differs from all other bodies, that go by the name of oils; and contains but very little earth.

13. The matter, remaining in the retort, after all these operations, still continues black; but, if carefully taken out of the vessel, and calcined in an open fire, it becomes white, terrestrial, and retains its pristine figure. This history of animal, and vegetable earth, shews us the great affinity there is betwixt animals, and vegetables (*d*): and as they agree in so many respects, it is no wonder, that animals should often consist of mere vegetables, with the interposition of water, and the assistance of the concreting faculty; accordingly, we every where find, that the bodies of animals are, in many respects, only altered vegetables; the principal difference between them, consisting in their salts, which in many vegetables are acid or austere; contrary to what we observe in animals, where the salts are never found to be austere or acid. This at least holds of the juices of animals perfectly changed by the powers of the body into an animal nature. Again, the salts of most vegetables, obtained by burning, are fixed; whereas, no fixed alkaline salt has ever been found upon burning the bodies of animals. Some vegetables, however, contain a volatile salt, like that of animals: for instance, scurvy-grass, mustard, &c. Earth, or oils containing a copious earth, seem to make, by their mixture, the principal difference betwixt the fixedness of animal and vegetable salt: whence it should follow, that earth is less intimately, and less copiously united with the oils and salts in animals, than in vegetables.

The correspondence betwixt animals and vegetables.

14. When vegetables are perfectly putrefied, their nature is so changed as upon burning to afford no fixed alkaline salt; but all their salt is now volatile, as in animals: whence elementary earth is by no operation so easily separated from all the other principles of vegetables, as by putrefaction; which wonderfully separates and divides the principles from one another; destroying the pristine form of the subject, and rendering the principles of animals and vegetables nearly the same. And thus putrefaction disposes their bodies to generate new matter in the air, water, and earth, fit for fertilizing the ground; supplying new vegetables, and supporting animals: whence, all putrefied bodies make excellent manure; and all animals, when putrefied, continually afford fresh matter for fertilizing the earth.

Putrefaction separates the earth in vegetables.

15. (*d*) To render the earths of the subjects of different kingdoms perfectly alike, the operation must be performed with great exactness, and the other principles be perfectly separated from the terrestrial one, by calcination, repeated solutions in water, filtration, &c.

*Fermentation
does not sepa-
rate the earth.*

15. But though putrefaction thus separates the earth from the other principles of animals and vegetables, and renders them volatile; yet fermentation does not do the same. Fermentation, indeed, moves the parts of vegetables strongly, for a long time, but can never extricate the earth from the salt and oil; and therefore does not bring vegetables to an animal nature; but increases the acidity of their salts, which by burning, afford fixed alcali; as we see in tartar. Indeed fermentation changes one kind of vegetable oil into alcohol; but does not thus convert all the oil of the subject.

*Earth from
burnt ani-
mals.*

16. The intire bodies of animals, being burnt to white ashes, and ground to powder, afford a pure earth, clear of all oil and salt; so that it cannot be distinguished from that procured by the above-mentioned operations from vegetables: and may therefore be used in all kinds of experiments, for the same purposes. And hence, we learn the nature of elementary earth, which enters as a principle into the composition of animals and vegetables; in both which the earth seems to be the same, without any considerable difference: for, tests may be made as well from the wash'd ashes of vegetables, as from the purest earth of animals, whether it be of fish, birds, beasts, or their horns, hoofs, flesh, &c. (e). This earth, therefore, has the same use both in animals and vegetables; and affords to both their solid support, or a firm basis for their other elements; all which are united to this earth, in order to be fixed, detained and formed into particular bodies: for it is the earth alone, that gives to each its form; and if deprived thereof, the other principles fall into an uninformed mass, or become unconnected, volatile, loose, and shatter'd: the earth being the band of union, that holds, ranges and associates the other parts together; and making one body of the whole, enables it to persevere and resist the air, the water, the sun, and a certain degree of heat, without falling asunder; tho' itself requires the assistance of water, or oil, as a cement to connect its own loose particles together into a solid mass.

*Earth in
fossils.*

17. We next proceed to enquire after this earth in fossils; and first, in fossil salts. If nitre, sal-gem, sea-salt, or any other pure, native mineral salts be dissolved in fair water, and long digested in close vessels, they will let fall an earth, not soluble in water: if the liquor be now poured off clear, evaporated to a pellicle, and set in a quiet, cool place, it will shoot into pure saline crystals, of a determinate figure, peculiar to each salt. And, if the remaining liquor be poured off from the salt so shot, and evaporated as before, it will thus afford saline shoots, tho' less pure than the former. By repeating this operation till no more salt will shoot, an unctuous saline liquor remains behind; which, when dried strongly, (for it grows dry with difficulty) affords some earth, that easily relents in the air, into an austere liquor. In each of these operations a little pure earth is always procured; which at length amounts to a considerable proportion, though the salt were a pure fossil one: and if the solution and crystallization be often repeated, all the salt becomes volatile, and vanishes insensibly into the air, leaving a mere

(e) See *Laz. Ercker* of tests and cupels.

mere earth behind; as was known to the ancient chemists, and is confirmed by the moderns (f).

18. If any of the above-mentioned pure fossil salts be dried, reduced to powder, and well mixed with thrice their weight of bole, brick-dust, or clean earth, and committed to distillation in a strong fire; they thus separate into an acid, volatile, corrosive liquor, and a fixed part remaining at the bottom of the vessel, along with the earthy substance wherewith it was mixed: if this fixed part be separated from the earthy matter by boiling in water; and the liquor be filtered and crystallized, it affords a salt, like that first employed in the operation; tho' nitre thus proves somewhat alkaline. The salt, so generated, being again crystallized, dissolved and inspissated, affords much earth, like the former: the acid liquor also, obtained from this salt, being rectify'd by a second distillation, leaves a yellow substance behind; which, when dry, likewise affords some earth: whilst the acid spirits, thus prepared, and deprived of all their earth, are so volatile, as in the open air, continually to go off in light fumes, that can scarce be confined; as we see in strong aqua-fortis, spirit of nitre, and spirit of salt. Hence it might be suspected that all the acid salts above-mentioned, are highly volatile, or would not naturally rest in our air, was it not for the earth that fixes their volatility, by closely adhering to them: and therefore, that all simple, acid, and alkaline salts are constantly volatile, when pure; and always fixed, when united with earth. But before this conclusion can be made, we must consider, that oil of vitriol, and *oleum sulphuris percampanam*, remain fixed in five hundred and sixty degrees of heat; tho' before rendered pellucid and freed from their fæces by repeated distillation. This indeed may proceed from the intimate mixture of some other body along with these acids, or a body either of a metallic or a terrestrial nature, so as not to be easily separated; since in the distillation, these acids fill the receiver with a very volatile fume, which flies swiftly into the air, and proves a noxious vapour, when any crack, by accident, happens to the distilling vessels. Again, we must consider that the most volatile acid salts, united with the most volatile alkali, turn to a compound half-fixed salt; and this, without the assistance of any fixed earth. On the other hand, alum by solution and filtration, as above, becomes more volatile, and affords a copious earth; yet if afterwards distilled, it affords a volatile noxious spirit, and leaves much calcarious earth behind. With this view, I have dissolved vitriol in water, digested the solution, and thus obtained a very large proportion of yellow ochre: and upon repeating the process of solution, crystallization, and separation several times over, the greatest part of the vitriol was turned to this yellow calx; whilst another part flew off into the air, leaving only a thick austere unctuous liquor behind. The ochre thus obtained, is not proper elementary earth, but approaches rather to the calx of iron; for tho' in other respects this analysis of vitriol resembles the preceding operation: yet the calx thus obtained turns to iron in a strong fire; or to copper, if the vitriol were blue. Whence it cannot be inferred, that earth enters the composition of these metals: nor do I remember to have ever procured true

Q 99 2

(f) See Du Hamel, *Hist. Acad. Roy. Ed. 2. p. 16. 17.*

earth from any metal: what is esteemed so, being convertible into glass; which shews it is of a metallic rather than a terrestrial nature.

*From fluid
and solid sul-
phurs.*

20. The liquid fossil sulphurs, as *asphaltum, bitumen, naphtha, petroleum,* &c. upon burning, afford black and acid foot and smoke; and when consumed, leave somewhat earthy behind them, which by farther calcination turns to a calx, from whence pure earth may be obtained, like that of animals, vegetables, and the saline fossils. So, if brimstone be sublimed in close vessels, it leaves an earth at the bottom; but scarce any at all, if the sublimation be repeated: and if pure sulphur be mixed with an equal quantity of fixed alkaline salt, by melting over the fire, and be then exposed to the air, it runs into a liquor, which lets fall a considerable proportion of true earth to the bottom; and this earth may be owing to the alkali. But, on the other hand, we are to remember, that the oil, which by mixing with the fossil acid, makes sulphur, contains much earth: whence also it is probable, that this earth may be thus regenerated in the resolution of the sulphur.

*Whether
earth be con-
tained in me-
tals.*

21. The antient chemists supposed metals chiefly consisted of quicksilver, and another principle, which rendered it malleable, and that these two were the only principles of gold and silver in particular; whilst in the other metals, there was besides added a certain unctuous inflammable matter, in their first formation: but the moderns, from their own experiments, every where speak of earth, in the resolution and composition of metals, as a vitrifiable substance, affording a firm basis to metals; tho' I conceive the earth, they here mean, is not our elementary earth, which I never could obtain from metals (g).

*In quicksil-
ver.*

22. If quicksilver, in its native form, as it comes from the mines, be strained thro' leather, it seems to leave a little earth behind; and if now distilled in a clean glass retort, it leaves but little faeces, inconsiderable in weight, and scarce deserving the name of earth, in the sense we have above defined it. If quicksilver, thus purified by distillation, be put into a strong vessel of green glass, well stopped down, and shook for a long time, as it may commodiously be, by fastening it to the sails of a wind-mill, a large part of the quicksilver will thus at length be changed, without any addition, into a grey or black heavy fine dry powder; which is an admirable remedy in case of malignant ulcers, and, as some imagine, undissolvable in any liquor. From this curious experiment, performed by M. *Homborg*, some have imagined that true earth is thus generated from the body of pure mercury, by bare mechanical motion; whilst others rather judge the quicksilver in this experiment deposits the terrestrial part, which nature added in its composition; so that the mercury, purified by this separation from its indolent earth, was expected to become more active, and fit for the purposes of alchemy, as being the mercury of the philosophers; but this powder is not elementary earth,

(g) The calces of metals are something very different from pure, elementary earth, tho' probably united with a proportion thereof. These are very apt, *per se*, either with a vehement heat to return to metal again, or else to run into glass; which is not the property of pure virgin earth, devoid of salts. The

excellent Mr. *Boyle*, with great probability, shews them to be the magisteries of metals, and has frequently reduced them back from this their disguised state, to that which is natural to them. See his *Discourse upon fire and Flames*.

earth, nor a principle of native mercury; as appears by calcining it; in which operation it undergoes several successive changes of colour; and again from its highly medicinal virtues in ulcerated cancers. But farther, this powder is dissolvable in several menstrua, and may be reduced to true quicksilver again. I have long operated upon this subject; and find it extremely hard to discover earth in mercury; but as easy to learn, that it may change it self into a thousand forms, and impose upon the unwary, whilst it self remains real mercury at the bottom.

23. Neither is earth to be easily found in the other metals, all whose calces are of a metallic nature; for, tho' they may be insipid, scentless, pulverable and light; yet, if mixed with flux-powders and melted in the fire, they recover their metallic form: whence they can by no means be reputed earth; otherwise it would thus be easy to convert earth into metals. And again, when metals are thus calcined, they may by the fire, with the addition of other bodies, be changed into glass; which is not the property of simple earth. It must however be acknowledged, that the impure metals, especially iron, may, by an artificial analysis, be brought to afford something approaching to an earthy nature; tho' this is small in quantity, and not true earth.

Whether obtainable from other metals.

24. Upon this occasion, I will relate the success of the pains I have for a long time bestowed upon the examination of metals. If gold, silver, copper, tin, or lead, be prepared after a certain simple manner, and exactly mixed with pure quicksilver, so as to be thoroughly dissolved, then long digested, and lastly well-ground together; the mixture, thus treated, will afford a large quantity of very black, fine, insipid, scentless powder, like that obtained from mercury; and this powder being washed away by water, the metallic mass will be left pure: which, being treated again in the same manner, affords more of this powder; tho' the operation be repeated for years, as I have often tried. If this process had been performed by those who assert earth to be contained in metals, they would probably produce it as a demonstration; but I, who have hitherto in vain endeavoured to finish these experiments, must acknowledge, that the powder so procured is not earth, but an extraordinary metallic production of admirable properties, richly deserving to be enquired into; for, tho' scarce any true earth can possibly be obtained from this metallic powder, yet many other very unexpected things may. When I carefully recollect the experiments I have made upon this subject, I durst almost affirm, that gold, silver and quicksilver, naturally contain no earth; but are of such a nature, that tho' divided into their least possible particles, they constantly remain fusible and malleable. I can say of gold, that by means of fossil acids, I have brought it into a liquor; that I have formed it into a soft paste; that I have several ways reduced it to a calx; that it may easily be turned into a volatile purple oil, changed into a butyraceous substance, converted to glass, and made to resemble earth; yet it always, by reduction, returned to the same unchanged gold, neither increased nor diminished in weight, or any other property. I have distilled gold with quicksilver, an incredible number of times over, but always found the same gold behind; and have constantly had the like success with quicksilver. Whence I cannot

Result of many experiments upon metals.

but

but have a high veneration for the ancient alchemists, who plainly assert, that gold and silver proceed from nothing but pure quicksilver, and a condensing sulphur; whilst the other metals are formed of a less pure mercury, and a fouler sulphur, differently combined.

*Corollaries
from the his-
tory of earth.*

*Affimilation
and propaga-
tion owing to
earth.*

*Bodies having
the same
earth, con-
vertible into
each other.*

*Iron nearer to
earth than o-
ther metals.*

25. From the preceding history of earth, we may draw the following conclusions: (1.) That the same simple elementary earth contributes as a constituent principle, to form the particular corporeal fabric of animals, vegetables, and some fossils of a less permanent and less simple nature; and in them all, serves as a firm basis to their form: whilst it unites the other principles to itself, and to one another, so as to constitute one determinate individual; at the same time, and by the same means, fixing and detaining other particles, of themselves too volatile, and keeping them from flying off; so as to persevere the duration of the individual for some time, both in the whole and every part; whence the texture of these bodies is not easily or quickly dissolved by the natural action of the air, water, fire, or their own juices. And hence the property of assimilating other substances into the nature of every body that receives nutriment, and consequently, the seminal property of producing their like, is principally owing to the efficacy of this earth, in constituting the peculiar structure of each individual: for these properties no longer remain after the particular texture, depending principally upon the earth, is destroyed or wanting in any body.

26. (2.) And hence all those bodies, which have the same earth for their principle, remarkably agree with one another in this respect; and generally also in their other concurring principles. Thus all animals agree, in many respects, with each other; so likewise do all vegetables. The principles of animals are daily changed into the substance of vegetables; and the bodies of animals, on the other hand, are constantly nourished and supported by vegetables, taken in as food, and assimilated; and the same holds likewise of several salts, having the same earth: thus nitre and sea-salt, which contain this same earth, are not remote from the nature of our bodies; and hence fixed alkalies, taken in a small quantity, are easily changed into our substance: for, if used by a person in health, at due distances of time, they lose their own fixed nature in the body, and manifest no fixed salt in the urine: whence we see those bodies which have this same earth for their principle, are easily changed into one another.

27. (3.) Thus iron, which of all the metals approaches the nearest to the nature of vegetable and animal earth, is the most intimately received by the bodies of vegetables and animals, so as perhaps to be digestible therein; whence it becomes an admirable and almost innocent medicine: whereas the other metals work with violence, as having not this earth, but quicksilver for their basis; whence they appear to be unchangeable or undigestible in animals or vegetables, and seem either foreign or noxious to the body: so that if they sometimes do service in obstinate distempers, not to be effected by other means, yet in other respects they seem to be insuperable by the vital powers.

28. (4.)

28. (4.) If therefore there was to be no such thing as earth or quicksilver in nature, perhaps all the bodies we know would be only volatile, moveable particles, or floating atoms, so subtle as not to be cognizable by our senses. Thus the alchemists affirm, that the metallic sulphur, before it fixes mercury, and is fixed by it, is of all bodies the most volatile and subtle: and that the like holds of other bodies, with respect to the fixing earth, has been sufficiently shewn above.

29. (5.) Earth affords us the principal instruments and vessels employed in chemistry; for all glass contains much true terrestrial matter, united to the fixed alkaline salt; and therefore owes its origin to earth. As for earthen vessels, china, chalk, &c. 'tis plain they chiefly consist of earth.

30. (6.) Again, pure earth, if mixed in a large proportion with fixed salts, prevents them from melting in a violent fire, as they would otherwise do, and at the same time renders them volatile: thus pure salt of tartar melts in a strong fire, and long remains fixed therein, excepting that it runs thro' the pores of the crucible; but, if well mixed with thrice its weight of pure earth, or calcined bone, it does not melt, but soon flies off: so likewise nitre and sea-salt, separately committed to a strong fire, flow and remain fixed, especially sea-salt; but, if mixed with earth, they do not melt, but become volatile, and change into acid spirits.

31. (7.) Pure earth is also of principal use in rectifying the volatile salts of animals or vegetables, and perfectly freeing them from the oil which is apt tenaciously to adhere therein, and foul them. The way is, to mix the earth with these salts, rendered impure by the adhesion of empyreumatic oils, and gently sublime them; whereby they rise perfectly white, and deposit all their oil in the earth: a separation that could not otherwise be so easily made. And the purer, the drier the earth is, and the larger proportion it is used in, the more perfectly this operation succeeds; especially if the subliming vessel be tall, and the fire gentle: which contrivance was formerly kept as a great secret.

32. (8.) The intermixture of this earth produces such a change in many bodies, as to deprive them of that flatulency which causes them to rarify and swell in distillation, and thus come over into the receiver, so as to frustrate the operation; as is the case in honey, wax, &c. if distilled alone: but, if mixed with a proper quantity of earth, which breaks the tenacity of their parts, and sets them farther asunder, they are commodiously fitted for distillation. And this holds not only of such viscous bodies as honey and wax, but also of blood, eggs, urine, &c. towards the end of the operation, when the more volatile part is come over, and the remaining part comes to be urged with a strong fire; whereby the whole mass, now grown of a pitchy nature, is apt to expand, rise at once into the neck of the retort, block it up, and burst the vessels in a dangerous manner: which may be prevented by throwing an earthy powder upon the matter thus to be treated; whence the addition of earth is of great use in the making of phosphorus from inspissated urine, with the utmost violence of fire.

*Elementary
earth distin-
guished from
vulgar
earths.*

33. (9.) What is here said of elementary earth, cannot be applied to common sand, which many unjustly take for earth. Sand appears, by the microscope, to be small transparent crystals, with many sides, and of very different figures; and with fixed alkali turns to glass in the fire: by means of sand, water gains a passage thro' the interstices of the soil, in order to its fertilization; whence, without this intermixture of sand, the soil would soon become of a stony hardness, for want of water. So likewise boles, and the medicinal earths are compounded bodies, and not the elementary earth we here speak of: 'tis plain they often contain something unctuous, saline, astringent, aluminous, or vitriolic, whereon their respective virtues depend. When water and fire have exerted their utmost action upon these boles, they approach nearer to true earth; and at the same time lose their medicinal qualities. Much less are we to imagine common earth, or the ground we tread on, to be our chemical or elementary earth; whilst that is so mixed a body as to contain clays, boles, sand, stones, water, air, oils, salts, and the principles of dissolved animals and vegetables, all wonderfully mixed together; whence we take it for a chaos of all the elements, and all the bodies composed of them.



OF MENSTRUUMS.

SECT. I.

Of MENSTRUUMS in general.

1. **W**E pass on now to another part of our business; for having considered the four first instruments of art and nature, we must come to a fifth, which is reckoned almost peculiar to chemistry; being that wherein chemists place their chiefest excellent; and whereto they ascribe the greatest effects of their art; viz. menstruums.

2. The term is a barbarous term; and denotes a body, which, when artificially applied to another, divides it subtilly; so that the particles of the solvent remain throughly intermixed among those of the solvend. This definition I principally admit, to distinguish accurately the manner wherein menstruums act, differently, from the other solutions of bodies, which chiefly happen in a mechanical manner; where the solvent recedes from the solvend, and is not reciprocally dissolved thereby: so that, after the solution, they separate from each other, according to their different specific gravities.

Menstruums defined.

3. The reason why this solvent was called a menstruum, is, because the chemists, in its application to the solvent, first used a moderate fire, for a philosophical month, or forty days; and hence called the solvend a menstrual solvent, and at length barely a menstruum.

The reason of the term.

4. It is therefore the property of a menstruum, to be it self equally dissolved, at the time it dissolves the solvend. And this property obtains in all solutions performed by the means of menstruums: but when the solution is perfected, it may happen, that the solvent and solvend shall separate. And *Helmont* writes, that in those solutions performed by the alcahest, the solvent and solvend separate into two distinct parcels, the one resting upon the other; but otherwise, this separation is seldom found in solutions. The divided parts therefore of the solvent, must insinuate themselves among the parts of the solvend, so as to divide and dissolve the body: and hence it appears, that this action of menstruums differs from all mechanical separations, where the dividing instrument remains entire and whole, both in the act of separation, and afterwards; as we evidently see in the case of a knife, sword, saw, piercer, &c. for all these instruments, whilst they divide, are not themselves divided, but remain almost the same as before. However, to consider the matter closely, there may be room to suspect, that the single particles of a men-

Property of a menstruum.

struum act, in solution, like the above-mentioned mechanical instruments; in which case, each particle of a solvent would have its proper size, figure, hardness and gravity, and act by these properties, which may be so far called mechanical. And here it will always be found, that every menstruum, whilst it dissolves, and because it dissolves, is necessarily divided into particles so small as to be invisible; and must therefore be fluid in the action: and, at the instant when the dissolution is performed, the solvend also must be dissolved into a fluid; and consequently, in the time of solution, the solvent and solvend become one fluid.

*Menstruums
divided.*

5: We must also observe, that many menstruums, before they act as solvents, are hard and consistent bodies; and, so long as they remain in this form, cannot act as solvents: but the custom has however obtained, of giving them the name of menstruums. Whence the chemists of all times have said, that some menstruums are solid and others fluid; and this division may be esteemed just, according to the distinction above delivered.

*1. Into the dry
kind, before
solution.*

6. Therefore, (1.) the dry and solid menstruums may be again divided into their classes; the first whereof we make the six metals; gold, lead, silver, copper, iron, and tin; which, when cold, are hard and solid, but act upon one another after being fused in the fire: whence they may be intimately mixed, so as to make an apparently homogeneous mass; every particle whereof holds the same proportion of a different metal, as the whole. For if ten ounces of silver be mixed, in a strong fire, with an ounce of gold, a mass of eleven ounces will thence be obtained; a grain whereof being given to an assay-master, he will report that it contains one eleventh part gold, and ten parts silver. Another thing still more remarkable is, that it should be possible, by this means, to divide gold *ad infinitum*: for if a hundred thousand parts of melted silver were mixed, in the fire, with one of gold, and the least particle of the whole mass be examined by an assay-master, as above, the event will be the same: which shews the wonderful property metals have to divide one another by fusion. Thus we see, that the least particle of gold may be expanded thro' an immense mass of silver, so that every the least assignable particle of the silver shall always contain a proportionable particle of gold; and this, whilst the particle of gold remains unchanged amongst the unaltered parts of the silver. Hence we may learn, with what properties metals were originally created; and find something in them that will for ever remain incomprehensible to men. Perhaps it is with regard to this property, that the chemists so often repeat, that metals can only be opened by metals; that nothing but one metal can intimately enter and mix with another; and that the inner mercurial part of metals is a thing of infinite subtilty, and always the same. (2.) The second class of solid menstruums are semi-metals; such as antimony, bismuth, cinnabar, marcasites, and zink; which also, like metals, melt in the fire, and mix and divide one another to a surprising degree. They may also be thus mixed with metals in the same manner; cinnabar, indeed, with more difficulty, the rest with less: but when thus mixed with metals, the metals remain no longer malleable, so that they may be easily reduced to powder, tho' ever so ductile before; and this happens even in the least particle of a metal: which is another surprising particular. (3)

In

In the next place, come all the dry salts; as alum, borax, nitre, sal-ammoniac, sea-salt, vitriol, fixed alkali, and mercury-sublimate; for all these, when actuated by the fire, or fused, have wonderful effects as solvents, and often such as cannot otherwise be obtained. They are also subtilly divided by the fire; and intimately mix, not only with one another, but also with metals, semi-metals, and other things. (4.) In the fourth place, come hard, fossil, sulphureous bodies; such as sulphur-vivum, common brimstone, arsenic, orpiment, and cobalt; which manifest a wonderful property in the fire, and thus mix with one another, and with other bodies; and have such particular effects as solvents, that the like can scarce be produced by any other means. (5.) In the last place, we reckon those fossil bodies, which the refiners call cements; and which consist of salts, sulphurs, and brick, reduced to dry powders, and strowed betwixt plates of metal, in order to raise their colour, or separate one metal from another.

7. There are some menstruums, which being left to themselves, after having performed the solution, concrete into a hard mass, that appears of a simple uniform nature. And this apparent simplicity is often so great, that the mass seems pure, tho' made up of various things. If lead be melted at the fire, and mixed with melted tin, they unite as water with water, or mercury with mercury; and this holds in whatever proportion these two metals are mixed. When the mixture is viewed fluid in the crucible, no difference appears; and when cold, they make but one homogeneous, simple, solid mass: the case is also the same in all the metals, and in some of the semi-metals before enumerated. Thus, if a pound of tin be melted in the fire, and a scruple of regulus of antimony be added thereto, the mass, when cold, will appear uniform; but become in every part so brittle, that the least particle thereof will not be found to have the natural malleability of tin: and in every the least particle of the mass, a proportion of the antimony will always be found. So fixed alkali unites with sand in the fire: and there are numerous examples to the same purpose; in all which the solvent and the solvend are mixed in their smallest particles, and concrete together, so as to afford a new body, wherein no one could discover that different parts were concreated together, unless he knew the origin of the mass, or by other experiments resolved it into its component parts. So sulphur and mercury, by being ground together, turn to a black and dry powder; which being sublimed by a strong fire, makes an apparent simple body, called cinnabar. We must also observe, that many fluid solvents intimately dissolve some solid masses; and when the solution is over, become a hard, and, in some cases, a dry body. Thus, not again to mention the case of mercury and sulphur, we see that almost all the menstruums of metals unite with their respective metals into solid vitriols; and thus strong distilled vinegar, when it has dissolved shells, chalk and stony matters, separates from its water, and, together with the bodies it dissolves, forms a dry and hard mass.

8. But there are numerous menstruums that have a liquid form before they act as solvents; such are all those commonly called menstruums in chemistry; as vinegar, water, saline, acid, alkaline, and compound spirits, alkaline oils *per deliquium*, &c. And as all these are liquids, their action is

(2.)
Dry after solution.

(3.)
Fluid before solution.

the easier understood ; as being common, and what we daily see in the shops.

(4.)
*Fluid after
solution.*

9. In the last place, there are menstrooms which become liquid after their action of solution is over, and remain so along with the solvent. This is no where more evident than in the dissolution of five of the metals with simple mercury ; for when these are properly mixed, they make a soft paste, which may be diluted indefinitely by the addition of more mercury : but to make this amalgam hard again, there is scarce any known method among the chemists ; he that can do it, will be an excellent, and perhaps a rich artist : but the task is difficult. Moreover, all the liquid acids, after having dissolved metals in a large proportion, long remain moist, and cannot easily be dried ; whence many have imagined these solutions to be fixed metallic oils, and in vain sought great secrets therein : tho' it is no more than a way of collecting acid salts in a large quantity about metals. But there are numerous solvents which remain in a liquid form with their solvends ; so that we need dwell no longer upon this point.

*The action of
menstrooms.*

10. By considering these different kinds of menstrooms, it is easy to observe, that many of them united bodies, as well as separate them into minute parts ; for we frequently find, that the particles of a menstruum, after by their action they have dissolved the solvend, presently join with the particles thereof, so as to produce a new compound, often very different from the nature of the simple resolved body. We must, however, allow, that the parts of the solvent, after its concretion, no longer touch one another ; but are separated by the interposition of the particles of the matter dissolved. Again, the separating particles, which before constituted the solvend, are now separated from each other, by the interposition of the particles of the solvent every where between them. For this division, separation and new concretion of heterogeneous parts, there arises a great number of new bodies by the means of menstrooms. But this happens so much the more remarkably, when only certain parts of the solvent and solvend are united ; whilst, by the same action, others are rejected in this new concretion, and appear in another form.

*Further con-
sidered.*

11. Hence therefore it is plain, that the parts of menstrooms apply themselves to the parts of the solvend ; and that this union principally happens at the time the solution is performed : whence a certain cause is here required to make the particles of the solvent fly from one another, and approach the particles of the solvend, rather than remain in their former situation. And the like cause seems to be required, to make the particles of the solvend, now separated by the action of the solvent, remain united with the parts of the menstruum that made the solution ; rather than, after the solution is made, to suffer the dissolving and dissolved particles to unite, by the affinity of their own nature, into homogeneous bodies. This deserves to be carefully considered, and remembered.

*This action de-
pends both
upon the sol-
vent and sol-
vend.*

12. And here, whatever the cause is, it must be sought as well in the solvend, as in the solvent ; for the action is reciprocal. Thus, whilst *aqua-regia* dissolves thrice its weight of gold into a yellow liquor, the parts of the dissolved gold remain united with those of the *aqua-regia* ; so that the particles of gold, tho' eighteen times heavier than *aqua-regia*, remain suspended therein :

therein; whence there must evidently be a certain mutual corresponding power between each particle of the gold and *aqua-regia*, whereby they mutually act upon, embrace, and detain each other; otherwise the particles of the dissolved gold would fall to the bottom, the saline particles rest thereon distinct, and the water float separate over them both: whereas they all three, tho' so different, unite together in the form of one simple uniform liquor.

13. If we were to deduce the cause from similitude of substance, the action of dissolution, so far as it is hitherto known, seems to be performed by a certain power with which the parts of the menstruum endeavour to attract the dissolved parts, rather than to repel them. We are not therefore to imagine this is a mechanical action, or an unfriendly commotion; but rather an appetite of union. This, I confess, seems paradoxical; but the phenomena of solution appear on its side. Thus, let any violent solution be considered; and the agitation, heat, hissing noise and tumult will be found to continue no longer than till all the parts of the solvent are united with those of the solvend; at which instant there ensues a perfect quiet: as remarkably appears upon throwing a piece of iron into weak *aqua-fortis*. *Owing rather to attraction, than repulsion.*

14. We must not omit to observe, that the whole solvent never act at once on the whole solvend; for only those particles of the solvent which touch some others of the solvend, first act in dissolving: and these being separated, fresh particles of the menstruum apply themselves to others of the solvend, and act thereon. *This action succeeds successively.*

15. Therefore, part of the menstruum acts upon that part of the body which it strikes off and separates: but whilst this separation is performed, there every where arises a greater motion in the menstruum, on account of the conflict made in the separation; and, by means hereof, the other parts of the menstruum are agitated, and applied to other parts of the solvend that were not before dissolved. *Excites it self.*

16. And tho' this agitation be an effective cause of solution; yet there is another which also promotes the action, viz. fire. What would be the case where this is perfectly wanting, no one can say; for it is impossible to exclude fire from any place, as was shewn above: but we certainly know that fire excites, promotes, and increases the action of menstrooms: for, in extreme cold, solutions are either not made at all, or slowly; but are soon performed with the assistance of heat. *Is increased by fire.*

17. But here, again, some menstrooms require a strong heat to make them act, as we see in mercury before it will dissolve metals; and some a smaller, as we see in sal-ammoniac, sea-salt, and salt of tartar, which easily dissolve in water. And some menstrooms act with a moderate heat; but lose their dissolving power, or even acquire a power of coagulating, by a stronger. Thus, warm water dissolves the white of eggs, which boiling water coagulates. *Different heat required in different subjects.*

18. To consider the manner wherein fire promotes the action of menstrooms, it appears: (1.) To be by impelling, moving and agitating the small particles of the menstruum, in the way of a mere mechanical motion: (2.) By its general power of expanding the substance of all bodies: and (3.) By separating the parts, so as to set them farther asunder; and thus heat of itself dissolves. *The operation of fire upon menstrooms.*

dissolves many bodies, joins the actions of other things with its own, and thus acts in conjunction. In all these respects, therefore, heat increases the dissolving power of menstruums, and causes them to act more advantageously; whence it often becomes a necessary condition. In most cases, also, heat is usually increased successively, during the solution; which is thereby the better performed, and commonly found to proceed the faster, as the heat increases. And even the action of those menstruums is increased by heat, which generate a great degree of cold in the solution; as we see upon putting sal-ammoniac into water: for in this case, if the water be warm, the salt dissolves the sooner.

S E C T. II.

Of the Action of MENSTRUUMS.

*The action of
menstruums.*

1. **T**HE changes wrought upon bodies by the dissolving power of menstruums, seem greatly to depend upon the minute particles of the menstruum now strongly cohering with the particles of the solvend; and can scarce be attributed to a true and proper alteration introduced by the menstruum into the dissolved particles. I am sensible, that eminent authors in chemistry are of a different opinion; but strict observation does not seem to favour them. For, tho' pure metals, such as gold, silver, and mercury, thoroughly dissolved by their acid solvents, at first appear changed in all their parts; yet they may be easily separated from their menstruums, in the form of a calx, which being fused in the fire, we thus recover the metal again unchanged. Whence it appears as if these menstruums had no other effect upon the internal nature of the metallic particles, than that of barely adhering to the surfaces thereof whilst divided: So, if the other metals should be mixed, in any proportion, with gold or silver, the nobler metals will always be left pure upon the test. I have dissolved gold and silver with mercury, above fifty times over; but always when I came to separate the mercury, I found the gold and silver I had employ'd in the original amalgam. If salts are diluted in any proportion of water, they may be recovered unchanged, by inspissation; and this, even after having been melted in the fire. And, if oils are mixed with salts, they may be separated again, almost pure. Fixed alkalies turn'd to glass, with vitrifiable earth, in the fire, may again be separated; and the glass reduced to its component parts. There are more instances of this kind, but these may suffice to intimate, that menstruums act in the manner above observed.

*The principle
seldom chang-
ed thereby.*

2. It may here be objected, that solution produces new bodies, or such as were not to be found before. Thus, if red-lead be dissolved in distilled vinegar, there arises sugar of lead; in which case the acid of the vinegar is attracted into the particles of the lead; yet when this salt of lead comes to be distilled in a retort, with a strong heat, the spirit of vinegar is not recovered; but a particular liquor obtained, that will burn

burn in the fire. This instance is just, and there are many more of the like kind: but, we must consider that the parts of the menstruum once adhering to the surface of the dissolved particles, cannot always clearly extricate themselves again; and frequently not only stick close, but remain united, so that they go together, and long continue in a state of combination. Hence, operators often imagine that the nature of bodies is destroyed, whilst there only happens such a simple conjunction of unchanged particles under a new appearance.

3. Thus, for example, the blade of a lancet, or knife, when naked, has the appearance of the power of cutting; but when remaining in the sheath, has not then the same appearance; tho', in themselves, the knife or lancet is still the same: and the easier they are to be unsheath'd, the sooner the appearance of their cutting power becomes manifest; but if the sheath was to be firmly connected with the blade, we should not scruple to say that the blade was chang'd. So, if a little cylinder of pure silver be gilt with gold, and put into aqua-fortis, all the silver will be perfectly dissolv'd away, and leave the hollow covering of gold entire, floating like a black film in the menstruum. Whence also, the acid parts of vinegar may be so united to certain parts of lead, as not to separate from each other upon distillation; but easily rise together. It would therefore be wrong to assert, that the acid of the vinegar was thus converted into a new kind of inflammable liquor by the contact of lead: it is highly probable, that this difference much oftener happens from combination, than from any change in the substance; and the like holds also in separation: for the substance dissolved, often consists of very different parts, some of which are perfectly taken up by the menstruum, whilst others are rejected and left separate; whence, after the menstruum is abstracted from the solution, there remains a different substance from what was employ'd as the solvend. And hence, without caution, one might be apt to infer, that the substance thus procur'd was a new one, produced by the changing power of the solvent; whereas in reality it is only produced by a bare separation.

4. Hence we may learn, that the action of all the known menstrooms depends upon motion; however abstruse some chemists may imagine their actions to be: for if a menstruum did not change the motion of the parts upon which it acts, those parts would remain as they were; in which case the menstruum, contrary to supposition, could have no action at all. But it is not easy to understand the physical manner wherein this motion is excited by the menstruum; which when alone was at rest, as well as the solvend till it began to be mov'd by the menstruum: but when, with a certain degree of heat, and at a determinate distance, these two begin to join, a new and considerable motion immediately arises in both; tho' this motion axisted in neither of them before: the origin whereof, we cannot fairly attribute to the common causes of motion; such as impulse, gravity, elasticity, magnetism, &c. but, there is here a particular cause, not common to all bodies, exerted between the solvent and solvend. This subject should be carefully enquir'd into; for he, who can learn the power of menstrooms, will understand the whole nature of chemistry; and be able to perform all its

*Act by motion
from a particular cause.*

noblest

*Menstruums
seldom act
mechanically.*

noblest operations. We are the more incited to this enquiry, by the authority of some great philosophers, who conceive that all the actions of bodies must be accounted for mechanically.

5. When a solvent divides its solvend by a mere mechanical motion, the particles of the solvent, at rest before, must always be agitated by some cause, that generates motion in the solvent; which cause is generally fire: and then the particles of the menstruum, thus put in motion, must strike against the surface of the particles at present combined together, in the solvend; communicate their motion thereto; and thus loosen and strike them off from the solid; whether this action be exerted upon the external surface of the solvend, or upon its internal parts. And this I take to be the only mechanical manner of acting; which tho' it may perform something; yet, perhaps, it is much less than men generally imagine. Fluids, indeed, every way surround, press and penetrate a solid, immers'd in them: but afterwards, scarce effect any farther change upon it, by means of their quantity, hardness, figure or weight. It is true, they may be mov'd by the action of fire, and thus act upon the external surface of the solvend; but this force is small, and always as capable of acting upon the fluid itself, as upon a solid contain'd therein; and, therefore, has no particular power of applying, compressing, and impelling the fluid upon the body to be dissolv'd: all which must depend upon some other cause. Thus a wedge could never cleave wood by being barely apply'd to it, or by being kept floating about it; but must first be fix'd into the substance, and afterwards be driven farther by an external force: an action not to be expected from the particles of a yielding fluid. But, suppose the parts of the solvent and solvend already divided by a pure mechanical force, so as to flow among one another; yet unless a farther power be added, the separated part, at first existing in a fluid form, will soon disengage and range themselves according to their respective specific gravities, and not remain suspended together in the fluid. So, when water by its motion wears away metals, stones, or other hard substances, a mere mechanical force thus divides them into minute particles; and upon resting, a fine powder falls to the bottom of the water, and cannot even by shaking be made to mix permanently therewith. So, again, when boiling water dissolves bodies compos'd of oily and earthy parts, the oil soon floats to the top, and the earth falls to the bottom: and these, indeed, may be called mechanical solutions. In like manner, rivers, winds, concussions of the air from the firing of guns, thunder, &c. have this kind of action; but after the solution is made, the solvent and solvend here separated from each other, according to their gravity, as soon as the strong concussion ceases. Thus, when antimony is melted in a strong fire, along with salts and other metallic bodies, the whole seems to be, thus, intimately mixed; but when remov'd from the fire, a scoria rises to the top, and the pure metallic part sinks to the bottom. Repulsion, also, may cause bodies to separate, after they were mix'd together by shaking; as we see in oil and water, or alcohol and oil of tartar *per deliquium*; where, not only gravity, but also repulsion occasions a separation, and suffers similar things to unite with similar. Some metals also, when

when melted together, do the like; as appears remarkably in M. Homberg's method of purifying silver. In short, those menstruums alone appear to act mechanically, which by a bare mechanical motion, arising from their magnitude, hardness, figure, weight, and impulse, first attenuate bodies, then directly separate from them again, according to their specific gravities; by which kind of solution no great change can arise: and, by this mark, I judge, we may know whether a menstruum acts mechanically or not, and easily distinguish such menstruums from others.

6. When a solution is performed by any menstruum, so as that the dissolv'd particles remain equably mixed with those of the solvent, tho' they both, at first, differed remarkably in their weight; such a solution may be esteem'd owing in part to the general mechanical power, which here, almost universally concurs, but principally to another action arising from the particular or peculiar property in the solvent with respect to the solvend; and *vice versa*: as by this power the particles of the one attract the particles of the other; and thus both are separated from their former concretions, and afterwards intermix or unite with each other, so as to form numerous new species of bodies.

What solutions are not mechanical.

7. To illustrate this by an example; if a ball of soft clay be put into water, and set over the fire so as to boil, the parts of the water now put in motion by the fire, will divide the clay into small particles; and thus mix them throughout the body of the water, whilst the boiling continues; but, when the external force of the fire ceases, and the water comes to rest and grow cool, all the clay falls to the bottom: whence, I could chuse to call this a mere mechanical solution; because, in this case, the particles of the water being put in motion by the fire, agitate the parts of the clay, without having any farther action, after the motion, given by the fire, ceases to act.

An instance of mechanical solutions.

8. But, if a ball of sal-gem, whose gravity is much greater than that of water, be boiled in four times its quantity of water, all the salt immediately dissolves so perfectly, as to remain totally imbib'd, suspended, and uniformly diffused in the water, even after it grows cold and is thoroughly at rest; and this, tho' the salt was so much heavier than the water: whence it appears that there is a power in the water, whereby it in such a manner unites to itself the particles of the salt, that they cannot be separated from it by their own gravity, but remain suspended: whence we have an intimation, that there are fewer menstruums, which act by a mere mechanical force, than men commonly imagine. Thus water dissolves ice and water; alcohol dissolves alcohol; and similar fluids dissolve similar. But there are various degrees, wherein the particles of different menstruums adhere, closer or looser, with the particles of the body dissolved: whence, again, arise numerous differences in the corpuscles produced by menstruums; some being so permanently compounded, as not to be resolv'd into the simple particles again, of which they were compos'd; whilst others easily let go the parts they had acquir'd in the solution: and these degrees are almost infinite.

An instance of a solution not mechanical.

9. In conformity with what is above delivered, we may divide all the known menstruums into four distinct kinds; with respect to the different manner of their dissolving. (1.) Thus, under the first class, I reckon all

Menstruums divided into four kinds according to their manner of dissolving.

those which act by a pure, simple mechanical power; and, whose action therefore, may be explain'd by the same mechanical principles, or the common powers of acting; which belong to all bodies universally: but, these menstruums are few, and commonly, extremely simple. (2.) To the second class belong those, which whilst they in some measure act by a mechanical motion; yet, at the same time, principally owe their efficacy to a certain repelling power. (3.) The third class are such as chiefly act by a mutual attraction between the parts of the solvent and solvend; which are a very large number, and common. (4.) Under the fourth class, I reckon all those menstruums, which act by the joint concurrence of the several properties above-mentioned; and these are the largest number of all; since in almost every menstruum there is a concurrence of mechanical power, repulsion and attraction. And if it were possible to class menstruums according to the differences of their actions, and, thence to form lower classes thereof; chemistry might thus be brought to rule; and we be able to determine the event of every operation, *a priori*: and hence, chemical experiments might be made with the greatest utility, in other branches of natural philosophy.

*This division
illustrated.*

*viz. (1.) The
mechanical.*

10. We shall here attempt to give an example of each kind, the better to prepare the mind for what is to follow. By way of addition to what is above said of mere mechanical solution; let us consider the granulation of silver, by pouring it, melted, into cold water. Take an ounce of pure silver, put it into a clean, strong crucible, cover it close with a tile, put it into a gentle fire, first, and when almost ignited, give a strong blast-heat till the silver runs as thin as water: now take the crucible out of the fire, and holding it high in the air, pour the fluid metal, by a little at a time, into cold water, that rises at least a foot in the containing vessel; thus the parts of the melted silver will enter the water with a gentle hissing, and upon the first contact separate into small grains, and fall to the bottom, without occasioning the least farther change, either in the silver or in the water: whence we learn, that the melted silver thus divides the water, and is divided by it; whilst neither of them are altered by this division; but range themselves according to their respective specific gravities, if the same circumstances are carefully observed. The like experiment also succeeds in gold.

*(2.)
The repelling.*

11. But if the like experiment be made with copper, as soon as ever the melted metal touches the water, the whole substance of the copper instantly recoils and flies off with an incredible force, divided into such subtle particles, as scarce to be found again; the wonderful repelling force, here exerted, scarce suffering any two particles of the metal to remain united. Whence, we learn that there may be menstruums, which like the water in the present case, may surprisngly dissolve the solvend by a repelling power: and, if gold, or silver, were mixed with the copper, and melted together, then poured into water, the effect would be similar. So that experiments of this kind, are not to be rashly ventured upon, for fear of mischief.

*(3.)
The attract-
ing.*

12. The next example will shew, that different bodies unite upon contact, and dissolve each other. Take four ounces of the flowers of sulphur, put them into an unglaz'd earthen pan, covered with a tile, to prevent the sulphur from

from catching flame, set it over a fire, so gentle, as barely to keep the sulphur melted: put six ounces of pure quicksilver into a strong clean linen-bag, and suspend this bag over the melted brimstone, which being uncovered, gently squeeze a little of the quicksilver into the melted sulphur, and stir them together, with a heated spatula, till thus by degrees, all the quicksilver is perfectly mixed in; whereby a black, brittle, stringy mass will be obtain'd; which, if viewed thro' a microscope, shines and appears metallic. Here we see a dry fluid solvent, and a dry, hard solvend, upon the contact of their minute particles, concrete together by attraction so strongly, as not again to be separated by fire; but upon sublimation, ascend united, and form cinnabar. These substances, which thus unite, are very different in their origin, gravity, kind, and degree of volatility, and little disposed to unite when entire; yet their particles coming into contact, they retain each other tenaciously. The causes of this union are, first, fire, which melts the sulphur, and divides it into its particles. Secondly, the division of the mercury, by passing thro' the linen-bag, as thro' a fine sieve, and falling by a little at a time, into the sulphur. Thirdly, the constant stirring of them both together. But these three causes only apply the mercury to the sulphur. The fourth cause, therefore, is a power in both, whereby, when touching in many surfaces, they attract each other so strongly, as to require a great force, or a stronger attractive of either, before they will separate again; and this mutual attraction is the principal cause of the effect. From whence, fifthly, arises so firm a cohesion, as the last effect, that tho' sublim'd in a close vessel by a strong fire, they do not separate into sulphur and mercury again, but rise in minute particles of cinnabar, the smallest of which consists of sulphur and mercury united: and, tho' this cinnabar be resublim'd, these parts are so far from separating, that they are thus more intimately united. Indeed, the cinnabar does not rise the second time so easily as the first; but, in each operation becomes less sublimable, and at length extremely fix'd in the fire: whilst in the mean time, the mercury does not fly off, but remains bound down by the sulphur; and this, tho' the fire be violent. Hence, I do not wonder that novices in chemistry, upon seeing this experiment, should expect that metals might be made by the intimate union of sulphur and mercury in the fire: especially when all the adepts expressly agree, that metals are composed of these two principles. But such novices receive the reward of their credulity: for in all these trials, the sulphur still remains sulphur; and the mercury returns from it unmeliorated, when another dry menstruum is added, which attracts the sulphur stronger than the sulphur attracts the mercury. Thus, if twelve ounces of cinnabar, made ever so fix'd by repeated sublimation, be ground to powder, and well mix'd with an equal quantity of clean iron-tilings, then distilled with a strong fire, all the mercury comes over, and falls, in its own native form, to the bottom of the water put into the receiver for the purpose; leaving behind in the retort a fixed mass, made by the union of the sulphur and iron: which two, always unite more eagerly than sulphur and mercury. Fix'd alkali may here be used instead of iron: for that also, when

melted by the fire, dissolves the sulphur, intimately unites with it, and sets the mercury at liberty: quick-lime, also, will do the same.

13. As another example of a merely attractive menstruum, take two drams of flower of sulphur, and three drams of mercury, grind them together in a glass-mortar, the longer the better; the mercury will now gradually disappear in its own form, and unite to the sulphur, which also disappears in its form; and from the intimate mixture of the two, a very black powder at length arises, after passing thro' various degrees of colour, which becomes the more black, the longer the trituration is continued, and the closer the two substances are united. This black powder upon resting, soon spontaneously concretes into a mass, wherein the mercury is cover'd, fix'd and detained, so as to be thus safely given to animals in a large quantity, without acting as mercury upon them; nor can it be separated from the powder by any other means, than by the distillation above-mention'd, with iron-filings, &c. and if sublim'd alone, it also produces cinnabar. The alchemists have consider'd this operation with expectation of gain; calling the black powder thus made, the crow's-head; which is by them said to appear in the beginning of their great work, upon the exact union of the two principles, sulphur and mercury. Here, therefore, we have another example of a dry fluid menstruum, and a solvend, divided in their parts by a bare mechanical rubbing them together, and afterwards uniting by an attractive virtue, so as not to separate again.

(4.)
*An instance of
the attractive
and repellent
fluid.*

14. As an instance of the attractive and repellent kind, take a pound of common antimony, reduc'd to powder, melt it in a clean crucible, close cover'd, till it runs like water, and discharges a copious white fume; then take the crucible out of the fire, and let it rest in a quiet place till perfectly cold, when the surface of the antimony will appear rough, unequal, and full of holes: then, upon breaking the crucible, you will find the bottom part of the mass solid, metallic and shining; but the upper part porous, white, yellowish, and lead-coloured. Whence we see, that the fire, by melting the antimony, had dissolv'd its metallic and sulphurous parts; which, being thus set free, range and associate themselves differently, the metallic with metallic, and the sulphureous with sulphureous, whilst the metallic repels the sulphureous, and *vice versa*: so that in this case, fusion by the fire, repulsion, attraction and gravity, acted together, whilst the solution was made. If this experiment be suppos'd not to shew the nature of a menstruum; yet it must be allow'd, that many particulars may hence be learn'd which happen in the actions of menstruums.

*By several
concurring
ways.*

15. But farther, to shew how menstruums may act by different concurring ways; take an ounce of salt of tartar, and half an ounce of flower of sulphur, heat them, and grind them together quick in a hot mortar, in a dry and warm air; put the powder into a crucible, cover it close, and set it in the fire, where the powder will soon melt, tho' the fix'd salt, when alone, melts with difficulty. Pour the melted matter upon a clean stone, where it will appear an uniform mass, that soon runs in the air, especially if it be ground to powder, and thus presently turn into a red oil: whence we see, how strongly a dry menstruum may unite with the dry body of sulphur,
which

which alone does not dissolve in water; but now, by the power of the menstruum, presently dissolves with the moisture of the air, which it seems greedily to attract.

16. The following is still a more curious experiment, to the same purpose. Take four ounces of fine antimony, reduc'd to a subtile powder, grind with it two ounces of hot and dry salt of tartar, in a heated mortar, and a warm and dry air, the pestil also being made hot; put the mixture into a crucible, and melt with a strong heat, that the powder may run thin; then pour the melted matter into a melting-cone, and, when cold, knock it out: thus we shall have an uniform mass, perfectly mix'd thro' its whole substance, by flowing in the fire like water, and now resembling glass; being of an ash-colour, a caustic taste, and dissolving in the air into a purple liquor. Hence the fix'd alkali, the sulphur, and the metallic part of the antimony are, by the action of the fire, first minutely divided, and then again united into one uniform substance; which rarely happens in other cases.

17. Again, take an ounce of pure silver, and three ounces of fine copper, melt them in a crucible with a strong blast-heat, and a pit-coal fire; when perfectly fused, pour them into an iron ingot: thus you will have an uniform metallic mass, made by an intimate mixture of the two metals, which cannot now again be scarce separated, without the assistance of lead upon the test. In this experiment, one metal becomes a menstruum to the other, as soon as they are both melted together, whilst each of them coheres more strongly to the other, than to itself: for, in every particle of silver there is here an uniform, constant proportion of copper: and, tho' they differ in weight, they do not separate from each other; the fire thus melting and mixing them together, without being the cause of their mixing so proportionably. This operation, therefore, shews, that the mercurial part of the silver unites itself so strongly to that of the copper, as not to let it go again; otherwise the melted silver wou'd fall to the bottom of the crucible, and the melted copper float above it: and thus, after fusion, divide into two different strata; as oil of tartar *per deliquium* and alcohol, when shook in a glass, presently separate, upon standing, into two distinct fluids, and cannot be brought to mix. And here it deserves to be remark'd, that these metallic bodies, whether they concrete in the cold, or melt in the fire, always retain the same proportion to each other, in which they were mix'd. And these examples may serve to shew, how variously dry menstrooms act upon each other.

18. If we consider the doctrine and instances above deliver'd, we shall have a different notion of the solution of bodies by menstrooms, from that commonly entertain'd by chemists, and such philosophers as endeavour to explain chemical experiments upon just principles; who have all conceiv'd, that a certain mechanical acrimony, acting by an universal mechanical power, was here the cause of the effect: and when they found, that what dissolved one body, would not dissolve a softer, they have invented several ways to solve the difficulty and apparent contradiction. But as we purpose to enquire into nature by experiments alone, we must proceed in another manner: and when we regard all the circumstances of this affair, we are first to consider the nature of

The concurrent causes of solution, viz. fire.

of fire; which being examined, in all its degrees, by experiments, we find to be an almost universal solvent, as it liquifies almost all bodies, if applied in a proper proportion to them. For when we rise gradually, from the heat of the body in health, to the utmost violence of the focus of a burning concave, and apply various bodies to the several degrees, we shall find but very few which do not run or resolve into their minutest particles, with one or other of these degrees: for tho' some substances, as brick, &c. grow harder with a certain degree of heat; yet they vitrify with an intense fire, as we see in melting furnaces. And altho' a few bodies do not melt in the strongest fire hitherto known; yet, who can say they would not melt in a stronger? We must therefore acknowledge, that the power of heat is very great and extensive in the action of menstrooms. The mercurial parts of metals could never be so uniformly united as they are, without the assistance of fire.

Trituration.

19. Again, in order to understand the action of menstrooms, we are to observe, whether any mechanical, strong, or long-continued attrition be concern'd; as this may often supply the want of fire, by attenuating, dividing, and rubbing the parts of bodies together; whence their fine particles may act upon each other, and at length intimately unite. Thus, by means of M. Langelotte's (a) mill, gold is said to have been ground into a potable liquor; upon which subject the author has wrote an express treatise. And we read in M. Homberg's papers, that all the metals, even gold itself, have been perfectly dissolv'd, and turn'd to liquors, by long grinding them with pure rain-water.

*By repulsion
and separation.*

20. Next, we are to consider, that bodies may happen to be dissolv'd after undergoing the operation of fusion, trituration, or feeling the joint efficacy of both: for when thus the bodies are divided into minute particles, and intimately mix'd, there hence frequently arises an opportunity for them to exert a repelling force, which before was latent. This being an observation in the more secret practice of chemistry, we shall illustrate it by an example. Melt pure lead in an iron ladle, then add to it thrice its weight of pure quicksilver, mix them together, and you will thus have a white amalgam, shining like silver, capable of being kept for years unalter'd: if this amalgam be ground in a glass mortar, with a glass pestle, the whole mass soon turns perfectly black; and if water be added to it, and ground therewith, then pour'd off, it takes away the blackness, and leaves the amalgam pure again, and capable of being kept as before: but, if ground again, it again grows black; and this, after numerous repetitions, as I have tried. Whence it is plain, that the mercury

here

(a) We find in the *Philosophical Transactions*, N^o. 87 an account of a letter written by this Dr. Joel Langelotte, chief physician to the duke of Holstein, wherein mention is made of his way of grinding gold; and two engines of philosophical mills, are there described for the purpose; with one of which, in the space of fourteen natural days, he reduced leaf-gold to a dusty powder, and putting it into a shallow retort, placed in a sand-heat, he thence obtained, by gradually increasing the fire, and giving a strong one at last, a few very red

drops; which, digested *per se*, or with tartarized spirit of wine, afforded a pure and genuine *Aurum potable*. The success of this operation, the doctor attributes in great measure to the salt of the air, which in grinding plentifully mixes and unites itself with the gold: but this particular he then designed to give farther proof of, in his account of some uncommon experiments made in the laboratory at Gottorp. By means of trituration he likewise declares, he obtained the genuine mercury of antimony.

here mix'd with the lead, does not repel this black matter either from itself, or from the lead, unless this mechanical triture be used; whereby the mixture is attenuated, its parts closer applied, and more intimately conjoin'd; whence there arises a power in the mercury upon the lead, and of the lead upon the mercury, whereby the matter, foreign to both, is repell'd and separated from them: which could scarce be done by another operation. And if the amalgam, thus made, be several times distill'd with mercury, and cohobated; thus also, as in the former case, the same black matter may be obtain'd, and wash'd from it, by trituration with water; whence a repelling force is thus again plainly introduc'd; by means whereof the separation is afterwards easily made: and by no other methods that I know of.

21. It often happens, that the parts both of the solvent and solvend, *By attraction.* when fused or agitated by the fire, or attenuated and mix'd by trituration, manifest a power of attraction and combination, that was latent before; and this often in a new, wonderful, and very effectual manner: whence proceeds a great variety of bodies that did not appear before, and are scarce producible by any other means; as we see in the preceding instance of the amalgamation of lead; where, upon triture, there arises a wonderful union of the mercurial metallic particles, by this attractive power; which manifests itself after the repelling power had first separated the heterogeneous parts that prevented the homogeneous parts from coming perfectly into mutual contact: but when the foreign matter is separated, in the manner above explained, the purified mercurial particles of both kinds, coming more intimately together, produce somewhat that was unexpected.

22. Lastly, when a menstruum, by this means, has dissolved a body, be *Whence new productions.* the manner of action what it will; and if after the solution is completed, the menstruum be totally separated from the dissolv'd substance, so that they both exist separately again; the dissolved body is thus obtain'd under a different form, and generally changed into a calx, or some new kind of substance.

23. Hence we learn, that nearly all menstrooms. even the solid kind, are, *Solid men- struums act as fluids.* at the time of their action, in a fluid form; unless we except the case of trituration, which of itself often renders bodies fit for solution: but then, to make the dissolution perfect, the trituration must be so exquisite, as to render the bodies almost fluid.

24. The following experiment is an instance wherein all the above-men- *One instance tioned causes concur at once in dry menstrooms; viz. fire, triture, repelling of all the power, attractive power, and mechanical force; so as to produce all the effects, causes uniting. viz. attenuation, concretion, separation and change. At the same time, this will be an example of a just procedure in making the like experiments. Take sixteen ounces of antimony, purify'd by a simple fusion in the manner above mentioned, reduce it to fine powder; this powder we know consists of common brimstone, intimately intermix'd with the mercurial part of the antimony; as is the case in common antimony itself, tho' no sign of these two different parts appears, even by the microscope. Then take twelve ounces of Rhenish tartar, reduc'd also to fine powder, and six ounces of pure pulveriz'd nitre; dry them all separately to the highest degree, and mix them perfectly well together*

together in an iron mortar, and reserve this powder for the following use. Next, take six ounces of tartar in fine powder, and three of nitre, mix these well together, to be kept in readiness: now, put a clean iron ladle over a clear fire, till it becomes almost ignited, then throw into it a small portion of the compound powder of tartar and nitre; the mixture will immediately swell, boil, throw out small sparks, and burn with a livid flame, leaving behind a white and perfectly alkaline mass, intermix'd with spots of green: and if a fresh quantity of the same powder be thrown in, it produces the same appearances. Whence we see, that a mixture of an acid, vegetable salt, and a saline terrestrial one, fume, sparkle, burn, and turn to fix'd alkali, immediately upon touching the fire. It was above observ'd, that fix'd alkali, well mix'd with sulphur, instantly took flame in the fire; whereupon the sulphur was immediately dissolv'd into a new substance. And hence it appears, that if tartar, nitre, and sulphur, be mix'd together, and thrown, by a little at a time, into an ignited ladle; a fix'd alkali immediately arises, which lays hold of the sulphur, dissolves it, and turns it to a substance of a peculiar nature. From whence we may easily apprehend the effect that will follow upon applying the above-mentioned mixture of antimony, tartar, and nitre to the fire, in the following manner.

25. Set a large, strong crucible in the fire, so as to heat gradually and equably, without cracking; let it be capable of containing at least thrice the quantity of the powder to be thrown in; cover it with a tile, and when thoroughly ignited, take off the cover, and throw in two drams of the mixture; first well heated, with care to prevent its taking fire: it will instantly, upon touching the bottom of the crucible, burst into flame, smoke, and sparks, but grow quiet when ignited again. Throw in the same quantity after the same manner, and do this by degrees, till all the powder is used; at each time covering the crucible, after the matter is thrown in, till the struggle is over. When the deflagration is finish'd, raise the fire so as to make the matter flow like water, which may be tried by stirring it with a tobacco-pipe; keep it a while in this heat, then pour it into a dry brass cone, first heated, and greas'd on the inside with tallow, rather than oil, which being apt to contain water, might here have a terrible effect: a flame, like lightning, immediately arises upon pouring in the melted mass, on account of the tallow with which the cone was greas'd; and by this flame the matter is hindered from sticking to the metal. When all is grown cold, invert the cone, and strike it, upon which the matter will come out and appear divided into two different parts; the upper a brown one, weighing about fourteen ounces, and call'd by the name of scorix; which are brittle, of a fiery taste, and run in the air to a red liquor: these scorix consist of the fix'd alkali, made by the tartar and nitre; and of the sulphur of the antimony, melted into one mass, by the alkali, in the fire; and thus being repelled from the metallic part, it floats at the top, whilst the metal falls to the bottom by its own weight; which therefore constitutes the other part, and is of a white shining colour, like silver; being very ponderous, and on its upper surface bearing the figure of a star: this part would be truly metallic, but for its extreme brittleness, which renders it pulverable.

26. This last experiment illustrates all that was above delivered concerning the action of dry solid menstrooms; for, first, mechanical trituration here reduces three kinds of matter to minute particles, so as to render them intimately miscible. Secondly, the fire melts, moves, mixes, and unites all the three together. Thirdly, the oil in the tartar, and the sulphur in the antimony, taking flame together in the fire, fix'd alkali is thus immediately produced, and directly lays hold of the sulphur of the antimony; whence, by their attractive force, the alkali and the sulphur unite into one mass, that easily runs in the fire. Fourthly, at the same time, there arises a repelling power between the metallic part of the antimony, and the alkaline salt; which two can never be united in the fire, but always, in fusion, repel each other, and range themselves in different strata, according to their gravity.

27. And hence it plainly appears, why the more ponderous metallic part here falls to the bottom of the cone; leaving the sulphureous alkaline part at the top, and thus producing two new substances; viz. an alkaline sulphureous scoria, and a stellate regulus of antimony. Hence, a mere mechanical power, attraction and repulsion, act conjointly in this experiment, to produce first a solution, and afterwards a separation; the pulverization minutely dividing the heterogeneous parts, increasing their contact, and multiplying their surfaces; whilst the fire mixes them farther, by agitating them together, and exciting, increasing and continuing their attractive and repulsive powers, thus keeping the whole mass, and all its parts, in liquid fusion; the oil of tartar, at the same time, inflaming with the sulphur and nitre, and thus adding great strength to the fire. The tartar and the nitre, by a perfect deflagration, here afford a sharp fix'd alkali, which drinking in all the sulphur, strikes out from it the metallic part of the antimony, which it will not touch. Lastly, the whole heated mass increases the strength of the fire; whence the motion and concussion becomes the more violent, and throws off a copious fume, with soot and sparks; by which means, 34 ounces of the powder lose about 16 ounces in the operation; the regulus weighing only about 2 ounces and 3 quarters. This experiment should be carefully made; for if the crucible be not large, in proportion to the powder, it will not contain the matter, when it swells and boils; and unless the mixture be ground fine, it bounces and flies off in the fire: if the crucible be not thoroughly ignited, the matter thrown in will not fuse; and unless the powder be heated before it is thrown in, it may crack the crucible by its coldness. Each time that any powder is thrown in, you must wait till the detonation ceases, or till the matter becomes perfectly ignited, and runs, before you throw in fresh; otherwise the mixture that remains unmelted, collects to a solid crust at the top, and confines the matter underneath: which consisting of alkali, nitre, and sulphur, then acts like gun-powder, and soon explodes with great violence; which may easily be prevented by the above-mentioned cautions. Again, unless all the matter be made to flow thin, before it is pour'd out, the regulus will not be perfectly separated from the scoria; and if the melting-cone be not heated before the melted matter is poured into it, there is danger of its flying; and unless it be greas'd, the matter often sticks so fast to the metal, as not to be got off. If a single drop of water should accidentally

fall into the cone, the melted mass poured into it might hence be made to fly about in a dangerous manner. And lastly, if it be not quickly poured into the cone, whilst it remains very fluid, neither the regulus nor the scoria will separate exactly, or range themselves distinctly: so many cautions are required in this single experiment.

The mechanical actions of menstruums farther considered.

28. We may now proceed to a closer consideration of the actions of solid and fluid solvents upon their solvends; so far as they are explicable upon pure mechanical principles: and the great regard I have for mathematical merit, requires it of us. There is no known sensible body in nature, whose parts are so tenaciously, or so strongly held together, as not to be separated by a mere mechanical force, without the intervention or necessity of any other cause. Thus, even the diamond, tho' so remarkable for its hardness, we see may be saw'd and cut into any shape, and exquisitely polish'd; for which purpose, the lapidaries use only mechanical instruments, and mechanical motion.

The softest bodies may mechanically dissolve the hardest.

29. So again, the most fluid body may, by a mere mechanical motion, dissolve a hard one by attrition. Thus water, by continual falling upon metal or stones, wears or dissolves them away; for altho' the falling of a single drop has but little force; yet, by numerous repetitions, it produces remarkable effects. Soft leather being long rubb'd upon the hardest gems, metals, or glass, gives them a polish; and wheels of wood, kept constantly turning, will wear away any body applied to their surface, into invisible particles: whence it follows, that the continual renewal of any wearing body may grind away the hardest substances; insomuch that the softest bodies will thus, at length, resolve the most rigid, into particles so minute as to escape the senses.

Soft bodies may consist of hard particles.

30. And here we are to consider, that the least and ultimate particles of any menstruum, to us invisible, may possibly be hard, and almost unchangeable; tho', in any sensible bulk, they appear ever so soft to our senses: which observation seems to be confirmed by many particulars. Thus, the component particles of fire exceed all others in hardness, smallness, mobility, and immutability. No one hath hitherto observed any change in an ultimate particle of true air; tho' the air, by its force, produces many changes upon other bodies. Water, which is found so soft a fluid, consists of such very hard parts, as not to be changed by any weight, concussion, or pressure: and we formerly observed the same of the ultimate particles of earth. So alcohol receives no change in its particles, after ever so many distillations, digestions, and commixtures. So likewise, the distilled acid spirits of the mineral salts seem almost immutable, and consequently consist of extremely hard particles; notwithstanding that some have imagined them pointed, and consequently changeable; but the industrious *Homburg*, by digesting these spirits, in close vessels, for years together, with a constant heat, found them to be no where changed thereby: tho' vinegar, indeed, in the space of four years, was altered to another nature (b).

31. The

(b) See *Du Hamel. Hist. Ac. Roy.* p. 497, 498.

31. The instances just mentioned serve to shew, that the last particles of the softest fluids may be hard and permanent: whence it may be easily conceived, that the attrition of the ultimate particles of menstrooms, strongly agitated, and repeatedly applied, for a long time, to the surface of a body, consisting of corpuscles joined together so as to compose a dissolvable mass, may thus wear down and dissolve large and hard bodies into minute particles; as well as large bodies dissolve others, by being rubbed upon them. An example whereof we have in stones, wore away or made hollow by the constant dripping of water: and this, especially, by the assistance of fire, to promote the percussion, attrition, and collision of the surfaces of the bodies.

Hence fluids may dissolve solids mechanically.

32. But, in every mere mechanical dissolution, there occurs this difficulty, that the particles of the menstruum, applied to the surface of the solvend, easily fly off or recoil, so as not to act powerfully; but then we are to consider, that the weight of both the bodies may have a great effect; and also the weight of the atmosphere, as mentioned in our history of air. Whence it is certain, that all menstrooms, which act simply by a bare mechanical power, dissolve but weakly, unless some other power be added: on the other hand, we know, that a strong external compression of a fluid to a solid, greatly increases the dissolving power, *ceteris paribus*. Thus, bones are little changed by long boiling with water in an open vessel; but soon grow soft, and dissolve, in *Papin's* digester; where the parts of the water are strongly compressed, and driven or ground against the subjects. And thus we may clearly understand the first mechanical manner, wherein certain menstrooms act; viz. by the attrition of one body against the external surface of the other.

33. But when the particles of a solvent not only wear away the body of the solvend, by attrition from without, but at the same time lay hold of its internal parts, so as to dissolve the inner substance by attrition; in this case, the particles of the solvent seem to insinuate themselves into the pores of the solvend, and thus to act upon the internal surface, after the same manner as we have already explained of the external surface. So that here the principal difficulty is to understand, by what means the solvent enters the pores of the solvend; and here we have not all the light one could wish, because there are very few instances of merely mechanical solutions: whence we are obliged to make use of those wherein mechanical causes act conjointly with others.

34. The first condition requisite to this solution, is a proportional magnitude between the smallest pores of the solvend, and the particles of the solvent; for, if these pores are so large as to admit the solvent in a liquid form, the cause of the action is the same as before: but if the pores are too little to take in the simple particles of the menstruum, scarce any internal solution can happen. On which account, therefore, no dissolution frequently ensues, when the parts of the menstruum adhere to each other, so as to form large concretions, incapable of entering the pores of the solvend: but if these concretions are dissolved by water, into finer particles, and thus set farther asunder by the interposition thereof, they now may enter the pores that excluded

The conditions requisite to internal mechanical solution.

cluded them before; as in the following experiment: Put an ounce of highly rectified oil of vitriol into a glass-body, place the glass in water set over the fire to boil, then put into the oil of vitriol five drams of clean iron-filings; and shake the glass; upon which there will instantly arise a great rarification, without fume or ebullition; the matter in the mean time remaining swelled, but undissolved, and of a grey colour. To another ounce of oil of vitriol, heated in the same manner, pour three ounces of boiling water; if the water be added cold, the glass would burst; throw into this diluted oil of vitriol, five drams of iron-filings: upon which a violent ebullition, effervescence, and fume will arise, with a garlick smell; and the whole body of the iron be presently dissolved in a green liquor.

Viz.
Size of the
particles, and
so c.

35. Those two excellent authors *Bohn* and *Boyle*, say, that silver and lead will not dissolve in the strongest spirit of nitre; but, readily, if that spirit be diluted with water: the following experiments will shew how that matter stands. Into an ounce of the strongest spirit of nitre I could procure, I put half an ounce of red-lead, and found no effervescence nor solution ensue in the cold; then to an ounce of the same spirit, diluted with eight ounces of water, I put half an ounce of red-lead, and here also found they remained long quiet in the cold. Again, I put an ounce of pure silver to an ounce of the strongest spirit of nitre, and found no sign of ebullition or solution. To an ounce of the same spirit, diluted with an ounce of rain-water, I put an ounce of pure silver, and found these also remain quiet in the cold: but, upon applying these four containing vessels to the fire, I found all the menstruums begin to act, effervesce and dissolve; with this difference, that the strong spirit dissolved less, and slower; but the diluted spirit quicker, and stronger.

36. From these experiments we infer, (1.) That mineral acid spirits may be diluted with water. (2.) That the mixtion is promoted by shaking the vessel, so as intimately and equably to unite the water with the saline spirit, which might otherwise remain at the bottom, and suffer the water to float at the top; as appears, in part, from the unctuous veins appearing when they begin to mix. (3.) That thus, as many aqueous parts as the operator pleases, may be interposed between every two saline particles, by adding more or less water. (4.) That, by this means, the particles so diluted may be kept from uniting into larger saline concretions, and remain floating separately among the particles of the water intermixed. (5.) That hence the saline particles thus kept floating separate in the water, seem now capable of entering the small pores of the bodies to be dissolved, by being rendered minuter. (6.) That these saline particles, unless diluted with water, touch one another closely, so as to unite or concrete into larger masses, incapable of entering the small pores of bodies. From all which, our notion of solution above delivered, is rendered highly probable.

Their figure.

37. But farther, in order to understand the mechanical actions of menstruums, we should consider the figure of the particles of the solvent; for we learn from mechanics, that mechanical actions greatly depend upon the figure of the acting body. Thus, any body whatever, remaining the same in all respects except its figure, may acquire a power of performing many things

things which it could not perform before; and this merely on account of its figure: for instance, an ounce of steel may be formed into a sphere, a cube, a pyramid, a knife, a lancet, a dagger, a piercer, a chissel, a file, a saw, &c. all which answer different purposes, on account of their figure. In like manner, the same body may act differently as a solvent, according to the figure of its parts, provided the pores of the solvend are able to receive them; and hence it may happen, that the reciprocal power between a solvent and a solvend shall be sometimes abolished, or perfectly changed, when the figure of the surface of either, or both, is changed: but it is extremely difficult to prove this to the eye; it being scarce possible to render the ultimate pores or particles of bodies visible. But reason, which from visible objects infers the latent nature of what is invisible, shews that this is the case: unless we imagine the dissolving particles of bodies to be immutable: which, however, is not probable, because the ultimate particles of bodies seem not to be the same as their dissolving particles; tho' it must be allowed, that, in many instances, the dissolving particles themselves seem to be changed. But that an efficacious fitness for action may arise in bodies, on account of their figure, has been elegantly illustrated by Mr. Boyle, from the example of a lock and its key; whose figure and size give them a peculiar and singular power of acting. Whence we may gather, that the relative figure between the particles of the solvent and the pores of the solvend, may fit them to produce many singular effects in mere mechanical dissolutions; and therefore, that many remarkable changes of bodies may thus be brought about, by such solutions depending upon size and figure. Sometimes also, great and extraordinary effects may be owing to the form of a body, as we see in the casting of bells; where a mass of melted metal, cast into a proper form for the purpose, and hung in the usual manner, when this bell comes to be struck upon by the clapper, all the circular sections of the bell, from the top to the bottom, change their circular figures into innumerable ellipses, which return to circles again, with a quick reciprocal motion, backwards and forwards; thus occasioning quick undulations in the air, to a great distance; propagating tremulous motions, shudderings, and sounds; and hence producing changes in the bodies of animals, vegetables and fossils: and all which depends upon the bare configuration of the bell.

38. The following experiments are supposed of that kind, wherein the figure of the solvent is changed with regard to its solvend. To an ounce of well-rectified oil of vitriol, add, drop by drop, six ounces of pure alcohol, made without alkali, and shake the containing vessel every time; digest the mixture, for a considerable time, in a tall well-closed glass; then carefully distil, with degrees of fire, till the matter begins to grow black; upon which, change the receiver, and continue a gentle fire with caution: thus there will come over a sulphureous suffocating phlegm, and, at the same time, a dulcified, volatile, sweet-smelling oil of vitriol, about six drams in weight, to be carefully kept in a stopp'd glass. The liquor, thus obtained, produces very different effects upon iron, from those produced upon it by common oil of vitriol. Understand the same of strong spirit of nitre, carefully dulcified with thrice its weight of alcohol. So likewise strong spirit of sea salt, when
thus

thus dulcify'd, will not dissolve gold, but extract its colour, as Mr. Boyle has observed: and so the dulcify'd spirit of nitre will not dissolve silver, tho' common spirit of nitre dissolves it readily. Experienced authors attribute these different effects to a change in the figure of the dissolving particles: and whether this change be owing to the combination of the alcohol, to distillation, or to both; the form or manner of the solvents is here certainly changed.

Particles entering partially.

38. There is a third cause, of considerable efficacy, in merely mechanical solutions, arising from considering that the least corpuscles of a menstruum, having the requisite inflexibility for the purpose, may insinuate themselves partially into the pores of the solvend, so as to leave one part of each corpuscle prominent above the surface of the body to be dissolv'd; by which means, all the pores in the surface of the solvend will be struck full of points sticking out like bristles, without entering farther: when, therefore, the particles of such a menstruum are put in motion, they will constantly strike with a different direction on all sides, upon the particles thus sticking in the surface of the solvend; which points therefore will, hence, act as wedges, to shake and split the solvend asunder. It is highly probable that this is frequently the case; especially, if we reflect that in such solutions, the uniformly smooth surface of the solvend is commonly render'd rough and unequal: and in mechanical solutions, this third cause appears to be the principal one. Whence we may clearly understand the action to be perform'd in the way of cleaving, or splitting, with a wedge, here, first fix'd in and variously driven by the menstruum; the ultimate particles of the solvend being extremely numerous, and the pores of the solvent lying in every point of the surface of the solvend; as appears from the smallness of the parts after dissolution.

Fire. (4.)

39. Lastly, the fourth cause of mechanical solution is fire, which principally shakes, agitates, applies and re-applies the particles of every solvent having the three above-mention'd conditions: and without this, the three preceding causes could act no more than a wedge not driven by an external force. Thus, tho' the size, hardness, figure, weight, and elasticity of the particles of the solvent, should be fitted ever so much to the pores, resistance, and hardness of the solvend; nay, tho' the particles of the one should touch the pores of the other, and begin to enter them; yet without the action of fire, no solution could be effected. And not only fire acts thus upon menstrooms by itself, but also, as it excites a motion, concussion, and attrition in the air, here press'd upon, and apply'd by the weight of the atmosphere, against the surface of the menstruum. Whence, the elasticity, the weight, and the motion of the air, being put in action by the fire, increases the powers of the menstruum. And this is all, that I can any way derive from pure mechanics, in order to account for the action of menstrooms. Some great philosophers have imagin'd this was sufficient to explain all the phænomena of solutions: and, we allow indeed, that in every action thereof, all these mechanical powers may assist and co-operate; but, do not allow that these alone, without the intervention of other causes, can perform the whole business of solution.

40. On the contrary, it rarely happens that any menstruum exerts all its dissolving power mechanically. And hence, Sir Isaac Newton, in his researches, has found reason, from observation, to add other necessary causes. But, to pursue this matter closely; let us consider, when a fluid possess'd of none but merely mechanical properties surrounds a body at rest, having no particular relation to the fluid, besides the common mechanical one; this fluid being now at rest, can only by its weight, and the fineness of its parts, compress the external surface of the solid, and the internal one of the pores it enters: whence, by the laws of hydrostatics, we can expect only the effect of compression, without any separation of parts or change of figure, unless the body be soft and yielding, or has its pores filled with a lighter fluid than that which surrounds it; whence this lighter fluid may be condens'd in those pores, or dislodg'd from them. And hence the condens'd mass will change its figure, bulk, and gravity; but, at the same time, remain at rest, and cohere more strongly in its parts, rather than dissolve. If fire be now apply'd, all the particles of the fluid will be agitated; but still, if the fluid, and the solid, are each of them homogeneous, the case is still nearly the same, with respect to the menstruum; as the fire here acting equally upon all the particles of the fluid, at once occasions the body to be equally press'd on all sides. But indeed, so far as fire excites those unequal explosive motions of ebullition; the pressure now being unequal, may wear off some part of the body; especially if its surface be uneven; but this does little towards the business of solution, as we daily see it performed by menstrooms. Thus, we find that hartshorn does not dissolve so much by being long boiled in water, as it does when suspended in the vapour arising from boiling water. But if an elastic matter be lodg'd in the pores of a body to be dissolv'd; when this matter comes to be dilated by fire, it may discharge itself in bubbles, burst the parts wherein it was confin'd, and thus resolve the substance: which solution cannot be attributed to the mechanical action of the menstruum; but is owing to the fire, that rarifies and acts upon the elastic matter. Hence, I have been led to doubt, whether the air which contains oils, salts, spirits, and other menstrooms, ever acts in a mere mechanical manner upon the bodies it dissolves; especially since such bodies can scarce ever be found perfectly pure and simple: whereas, I have learnt from experience, that different parts, of different properties, are mix'd in with all such bodies; while these parts have respectively their own peculiar powers of attracting, repelling, and changing themselves many other ways. We must not, therefore, attribute more to mechanical power, than the author of nature has given to natural bodies; nor extend this power beyond its proper bounds, in accounting for chemical operations. This declaration is forc'd from me, by the regard I bear to truth; and may clear me from the imputation of pretending to explain chemical operations upon mechanical principles.

41. Having thus, therefore, dispatch'd the consideration of mechanical power in solution; we proceed to consider those solvents, which act by a particular virtue, and not by any general property of body. And these solvents we shall find so numerous, as to include nearly the whole number; which

The insufficiency of mere mechanical power in solution.

Menstrooms acting by a particular power.

which being extremely large, we are obliged to reduce them into classes under general titles: and this contrivance will not only help the memory, but afford an opportunity of ranging new discoveries in their proper places, according to the relation they have with known things; whence, also, their manner of action may more easily be understood.

S E C T. III.

Of aqueous MENSTRUUMS.

Class 1.
Aqueous men-
struums.

1. **T**HE first class of fluid menstruums we make to consist of water, and aqueous liquors. But, water in the form of ice, is a solid, which dissolves into a liquor, upon being mix'd with dry, or fluid salts, both of the fix'd, and volatile, alkaline kind; with fix'd, or volatile acid salts, compound salts, and the fermented spirits of vegetables; and this, even in the highest degree of cold: as was shewn in the chapter of fire, where this subject has already been sufficiently treated. As a fluid menstruum, it begins to act, in the next degree below that of freezing; or, in a heat of thirty two degrees by *Fahrenbeir's* thermometer: and never acts as a fluid menstruum, where it remains perfectly froze. The heat of water, unconfined, may be increased by boiling, from thirty two degrees, to two hundred and fourteen, without growing hotter in our climate, upon the earth's surface; but, as it heats the more, the greater weight of the atmosphere it is press'd by, its heat may be prodigiously increas'd in the bowels of the earth; so as, at great depths, to have, perhaps, a higher dissolving power upon many bodies, than any other known menstruum.

The heat of
water limits
it, dissolving
power.

2. It is the happiness of this age, thus to have assign'd and limited the dissolving power of our first menstruum, water, within thirty two, and two hundred and fourteen degrees of heat; where we may observe the beautiful manner, wherein nature acts: for, in many solutions where water is the menstruum, the dissolving power increases, and diminishes, with the degrees of heat. Thus, for example, water of thirty three degrees hot, dissolves a certain proportion of sea-salt, which prevents the water from turning to ice by the same degree of cold, that would freeze pure water; and this probably happens from the interposition of the salt; whereby, the surfaces of the particles of the water are prevented from coming into mutual contact. But, when the cold is increas'd far above the degree which freezes pure water, then the salt-water begins to contract, and the salt to collect at the bottom of the vessel in little crystals; and as the cold gradually increases, this water gradually deposits more salt, till at length, the water being nearly depriv'd of all its salt, turns to ice. During the whole increase of the cold, more and more salt is continually separated from the water; and, when the ice is thaw'd, all the deposited salt will again be taken up by the water. On the other hand, if water, thirty three degrees hot, has dissolved as much salt as it possibly could in that degree, and be afterwards gradually heated

heated farther, up to the degree of boiling; and upon the increase of every degree a little more salt be added, this salt will be dissolved every time, till the liquor boils; after which, it will dissolve no more, tho' boil'd for a long time.

3. To illustrate this by experiments; take an ounce of pure dry sea-salt in powder, put it into a clean chemical phial, and gently pour thereto three ounces of pure water; then set a glass in a quiet place, to receive the degree of heat at that time shewn by the thermometer. Having put the same proportion of salt and water in another phial, shake them strongly together in the same degree of heat with the former; adding at times a little more salt, till some remains undissolv'd at the bottom. Have also a third phial in readiness, containing the same proportions of salt and water as the first. Then put the second and third phial into a copper of water set over the fire to heat by degrees; thus the salt in the phial, that was not shook, will begin to dissolve; and upon the heat increasing, the salt will be found to dissolve much sooner and more copiously than in the first phial, now standing in a quiet place, and receiving only the heat of the atmosphere: so that by means of the heat apply'd, the salt is as well dissolv'd in the unshook phial, as in that which was shook. Into the second phial throw, as the heat increases, a few grains of dry salt, which will now be dissolv'd; and continue doing thus, till the water boils in the copper, when a considerable quantity of salt will be dissolv'd in this second phial; besides what was dissolv'd before by long shaking. When so much salt is added to this water contain'd in the phial, that it will not dissolve the last grain that was added; in this degree of heat take out the phial, and set it by to cool, upon which the pellucid solution will begin to grow opaque and turbid; a skin forming upon its surface, and salt falling to the bottom; so that, when it comes to be of the same temperature with the atmosphere, it will now have let fall nearly as much salt, as it had dissolv'd, by means of the increas'd heat, above that of the external air at the time. If, now, the first phial be examin'd, a large quantity of the salt will remain undissolv'd at the bottom; whilst the other part is dissolv'd towards the bottom, unmix'd with the rest of the water, and appearing in the form of a heavy, unctuous, viscous, fluid; and if not shook will thus, long, retain the same appearance; but upon shaking, it spreads in unctuous veins, through the body of the water above it, dissolves in it, and falls no more to the bottom. Another portion of the salt remaining at the bottom, now, again appears to dissolve in the same manner, and may, by shaking or heat, be mixt and united with the less saline water above: and this observation holds, till nearly all the salt put in, comes to be dissolv'd thro' the whole body of the water. In making these experiments, the two phials, put into the boiling water, are to have such long necks, that no water can exhale from their cavities with the heat apply'd: their necks also are to be heated, lest the steam of the water below should crack them.

4. From these slight experiments, the following conclusions easily flow; viz. (1.) That the parts of the salt and water are not here changed, but only so conjoin'd, that the water now touches the parts of the salt, as the particles of the salt or water before touch'd one another; which species

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of

of solution is a mere permixtion. (2.) That the increase of heat increased this power of permixture, so as to hasten the dissolution, and dissolve more salt in the same water; and this so long as the water can receive a higher degree of heat. (3.) Hence, also aqueous menstruums, saturated with salt, grow turbid in cold, and deposite saline crystals; but when heated, grow transparent again, and dissolve the salt they had deposited. (4.) That water and the salt dissolv'd therein condense by cold into crystals, which spontaneously resolve, upon the re-application of heat; as we see highly rectify'd oil of vitriol grows solid in the cold, but presently melts with warmth. (5.) That boiling water, saturated with salt, is heavier than water; whence, brine, in a boiling state, proves hotter, by the thermometer, than pure boiling water, and cannot be brought to boil without a greater heat than that of boiling water; whereas pure water may be brought to boil by setting a glass of it in boiling water. (6.) Fire, therefore, is the cause of the solvent power of water, and ceases to act without it; as appears evidently from freezing, and is abundantly confirm'd in our history of fire: for, upon the decrease of heat, the cold constantly and proportionably expels from water the salts it before held dissolv'd, so as, even to convert spirit of nitre into ice; whence, a high degree of cold, always exactly separates salt from water. We may add also, that cold disables water from dissolving alcohol. In the winter of the year 1729, I expos'd beer, wine, vinegar, and brine, in large, open vessels, to the frost; which, thus, congeal'd nearly all the water of these liquors into a soft, spongy kind of ice, and united the strong spirits of the fermented liquors; so that by piercing the ice, they might be pour'd off and separated from the water, which diluted them before freezing; and the more intense the frost is, the more perfect this separation: whence we see, that cold unfits water to dissolve alcohol, and the salt of vinegar: and it is probable, that the utmost possible cold in nature would deprive water of all its dissolving power. (7.) Hence we see, that the particular power of water to dissolve salts and other bodies, so as to unite them with itself, does not depend upon the water alone; but requires the assistance of fire to render the solution perfect. (8.) These discoveries being applied to the animal juices, especially to those of men, have a great and extraordinary use; as water is the principle and most copious of all the liquors contain'd in the healthy human body; so that in this, the other principles of all the animal fluids are dissolv'd, mix'd, held together, and kept fluid. As this water, therefore, is so liable to changes from heat and cold, it may wonderfully change the juices. Thus, how greatly is blood, drawn out of the veins, changed by cold from what it was in the body? And the urine of a healthy person in a cold season, soon deposite a gross sediment; which may again be taken up, by warming the containing vessel, so as to render the whole like what it was before: hence we may learn what great changes are producible in the body, from the changes which water undergoes by heat and cold. From the premises, one might be tempted to say, that the solvent power of water almost always increases in proportion to the heat applied, up to the degree of boiling.

5. But it is dangerous to please the mind with general truths in physics, or to extend our consequences beyond experiments. Thus in the present case there are numerous experiments, which would persuade one that the solvent power of water decreases, as the degrees of heat increase: for example, if balls be formed of flowet, mix'd into a paste with water, they will dilute and resolve with cold, or warm water, but grow hard, without dissolving, in boiling water. So the white of eggs mixes intimately with warm water, but coagulates and hardens by boiling therein: and this hardening begins with a certain degree of heat, and grows greater, as the heat grows stronger; tho' till this certain degree be arriv'd at, the increasing heat serves to dilute the subject the better. Understand the same of blood, &c.

6. Hence we should range into classes, those bodies which are always dissolv'd by water, in all the degrees of heat; for example, (1.) All the known neutral salts; as, sal-gem, sea-salt, nitre, sal-ammoniac, &c. (2.) All the known pure volatile alkaline salts, obtain'd from animals or vegetables, by putrefaction or distillation. (3.) All the fix'd alkaline salts obtain'd from vegetables by calcination. (4.) All kinds of acids naturally found in vegetables, and in all the acid salts; all kinds of native, fossil acid salts; with all the vegetable acid juices, which afford a spirit, or vinegar, by fermentation: then again, the acids obtain'd from woods by distillation, whether oak, guaiacum, sassafras, &c. distill'd vinegars, *oleum sulphuris per campanum*, oil of vitriol, spirit of alum, spirit of nitre, spirit of sea-salt, &c. (5.) Artificial compound salts, by the combination of acids and alcalies, so as to render them neutral; all which, easily dissolve in water; but tartar of vitriol with the greatest difficulty. (6.) Salts of the borax kind; which also difficultly dissolve in water, and require the assistance of fire, for a considerable time. (7.) The native salts of plants, artificially procured from vegetable juices by depuration and crystallization; which easily dissolve in water, and even run spontaneously in the air. (8.) The vegetable salts arising after fermentation, and called by the name of tartar; which difficultly dissolve in water, and require a strong heat. It is remarkable of this tartar, that it does not dissolve in wine; and requires twenty times its own quantity of water to dissolve it by boiling: and if the proportion of water be less, or the boiling heat begins to slacken, it presently shoots from the water in little crystals. All the other salts, except borax, nitre, tartar, and tartar of vitriol, not only dissolve in water, but even by attracting the moisture of the air: pure acid salts do this readily, so do the fix'd alkaline and volatile ones. It is difficult to obtain pure acids in a dry form, and not without the highest degree of cold; but fix'd alcali, taken in a melted state from the fire, presently attracts the moisture of the air, as soon as the heat is a little diminished: whence it is plain, that these salts have a latent power of attracting moisture; and consequently, that water exerts two distinct actions in dissolving these salt; the one attractive, and the other solutive; both which together, constitute the power of an aqueous menstruum. We must also observe that there are some salts highly attractive of water, and which upon their combination turn into a third substance, not easily dissolvable in water: thus, oil of vitriol attracts water strongly, and fix'd alcali with difficulty lets

go the water it had attracted; but, if the oil of vitriol and fix'd alkali be mixed in such a proportion, as to form a neutral salt, this salt will not easily dissolve in water: and there are other examples hereof, in the making of compound salts, tho' scarce any in so high a degree. And all these salts require a certain proportion of water to dissolve them totally. But, when water is saturated with one salt, it will still dissolve another, without increasing the degree of heat: thus, a saturated solution of nitre will dissolve a considerable proportion of sea-salt; and the saturated solution of these two, will still dissolve a proportion of sal-ammoniac.

Saline bodies.

6. In the next place, water, as a menstruum, dissolves all those bodies which are called saline, and contain some of the above-mentioned salts, as a principal part in their composition, mixt in among other parts which of themselves are neither salts nor saline bodies, but of another species. Under this class we reckon, (1.) the native soaps of vegetables; for such are all the ripe juices of summer-fruits, being a mixture of water, oil, salt, and spirit; and dissolving in pure water: for a farther account whereof, we refer back to the chapter of vegetables. (2.) Certain particular concreted juices, differing from the former, lodg'd and perfected in a particular part of the plant; as the pulp of cassia, manna, honey, sugar, &c. These indeed might be ranged under the first class, tho' they differ from them in the particulars here mentioned, and also as containing less water; they are however soaps, containing a copious oil, mix'd in with salt, so as perfectly to dissolve in water; without excepting even gums themselves. (3.) The more fluid juices of vegetables, circulating thro' the vessels, and whole structure of the plant; as the liquors afforded by the vine, the walnut, and the birch-tree, tapp'd in the spring. All the liquors of this kind, though differing in different plants, are vegetable soaps, diluted in a large proportion of water; and thence render'd extremely capable of being farther dissolved by more. (4.) All the known animal juices, except fat, easily dissolve in water, tho' none more easily than perfect bile; as I learnt by taking it fresh from the bodies of animals, and endeavouring to inspissate it with a gentle fire, so as to form pills thereof, for medicinal use, and to keep it long in an unaltered state: but I found the mass, thus obtained, dissolve spontaneously in the air. (5.) All the soaps made of express'd vegetable oil, and fix'd vegetable alkali, mix'd, by means of boiling water, with the fiery part of quick-lime, and brought, by boiling, into a hard mass. To these may be added all the soaps prepared from distill'd vegetable oils, united with the sharpest, driest, fiery alkali, heated and strengthen'd by quick-lime; and thus prepared to receive the oil, by pouring it thereon, and exposing the whole to the open air, at some depth under ground. To these we also add those other excellent soaps, obtain'd by a less known means, by mixing pure distill'd oils with a pure volatile alkaline salt, without the interposition of any foreign water, and barely by a slow, careful, repeated sublimation; whence admirable remedies are procurable. But the most subtil soaps of all are obtain'd by uniting the purest alcohol with the purest volatile alkaline salt; which, by a proper treatment, produce an exceeding volatile, saline, sulphureous and saponaceous substance, in the form of snow, vulgarly call'd the *ossa Helmontiana*; and by *Lully* spirit

rit of wine, quickned with sal-ammoniac. We may still add another soap, prepared by perfectly uniting salt of tartar with alcohol, by a secret treatment. In all these soaps, chemistry is perpetually discovering the most efficacious menstrooms, and physic the safest remedies. It is here remarkable, that tho' oils alone will not unite with water; yet, when join'd with the salts, they presently dissolve therein, whilst the salts alone are attractive both of water and oil: whence we learn the methods of dissolving oils in pure water. (6.) Under this saline class of bodies, capable of dissolving in water, we range vitriols, made by dissolving metals by means of salts, especially the acid kind; for, these dissolve totally in water, whilst they retain the true vitriolic form. Thus the vitriols of gold, silver, lead, mercury, iron, copper, and tin, brought into magisteries, salts, or vitriols, by proper acid menstrooms, and such a proportion of water as gives them a transparent crystalline form, are dissolvable in water; and this the easier, the larger proportion of the acid menstruum was used in making the vitriol: but when the water is exhal'd from these vitriols by a gentle heat, so as to render their crystals opaque, the metallic parts are thereby less disposed to dissolve in water; and, if highly dried, they will not dissolve at all: tho' they still retain much of the acid solvent. Thus, if an ounce of quicksilver, which is absolutely undissolvable in water, be dissolv'd in an ounce of spirit of nitre, and the solution be a little inspissated, this liquor may be diluted, in any proportion, with fair water; and if the solution of quicksilver in spirit of nitre, be suffered to stand in a quiet place, white, and somewhat transparent, caustic crystals will shoot at the bottom, capable of dissolving readily, and totally, in pure water; which crystals, being dried to a white, yellow, red or purple powder, will not totally dissolve in water. Whence we see, that water only dissolves metals, on account of the acid adhering to the surfaces of their particles; and therefore quits the metals so dissolved, as soon as the acid is remov'd. Thus we see, that metals first dissolv'd in acids, then largely diluted with water, become potable, so as to be receiv'd into the body, mix with the fluids, act upon the solids, and produce their peculiar effects, which are often very considerable; as an acid and a metal united act with strength upon the body; tho' this power lasts no longer, than whilst they remain dissolved; and their solution depending chiefly upon the acid, if that be taken away, the metal remains no longer potable, or fit to mix with the juices, but turns to a calx. Whence we may understand the cause of the efficacy of a vitriolic solution; which efficacy remains only so long, as the dissolving salt and the dissolved metal remain diluted together, in a large proportion of water; but when, by the weakness or inactivity of the dissolving salt, the solution drops its ochre, the liquor becomes inefficacious.

7. What is here said of the action of an acid, with respect to water, holds true also of those metals which are dissolved by alkaline salts: thus copper, dissolved in strong spirit of sal-ammoniac, so as to afford a fine blue tincture; if this tincture be depriv'd of its salt, it is thereby greatly chang'd, and lets fall a dusky powder. The same holds also of metallic solutions, made with compound salts: thus sal-ammoniac, or sea-salt, may dissolve metals in a certain manner.

manner, so that they may be diluted with water, and thus produce great effects upon the body; whilst their action depends chiefly upon their being dissolvable in water. And yet this does not hold of all metals; for tho' butter of antimony, (or a solution of the regulus of antimony, made by the strong spirit of sea-salt, contain'd in the mercury-sublimate) be highly acid; yet instead of diluting with water, it immediately, upon the affusion thereof, lets fall the antimony in a white calx; which being fused by a strong fire, affords a fine regulus of antimony no ways capable of dissolving in water.

*Earthy bodies
dissolved in
acids.*

8. If pure earthy bodies be first dissolv'd in acids, they may afterwards be perfectly diluted with water, so as to leave the whole body of the liquor limpid; and in this form they may also produce their own effects. Thus, chalk, dissolv'd in a large proportion of acids, may be diluted with any proportion of water: and I scarce know any earth but may be thus dissolved by some acid or other, so as to escape the cognizance of the senses. Whence we see, how unsafe it is to infer, that a liquor is free from earth, because it appears pellucid: even the true ultimate earth, obtain'd from the bones, &c. of animals, may be thus dissolv'd in acids, and then in water; tho' it be still recoverable, afterwards, by various means.

9. But tho' earthy bodies may thus be dissolved in water, alkalies cannot when intimately united with earth, be afterwards diluted with water; as plainly appears in glass, which consists of an alkali and an earth, intimately united, and is less soluble in water the closer the union: so great is the difference between the solution of earth, by one kind of salt and another. Alkalies, we see, subtilly dissolve earth into a fix'd, transparent, hard body, which resists the dissolving power of water, more than any other body: but it appears stranger still, that the subtil, volatile, alkaline salts of animals, intimately united with earth, should form a mass undissolvable in boiling water: for, the stones generated in animals, I take to consist of these two principles and oil; and in whatever part of the body such stones are generated, they commonly produce terrible effects; as having a power of attracting and joining to themselves a similar matter, from such animal juices as approach nearest to putrefaction; viz. the bile and urine: which containing salts nearly alkaline, these salts unite to themselves the fine earth, wore off from the parts of the body; and thus lay the foundations of new stones, or enlarge the old ones: and hence the daily increase of this monstrous production, that brings on terrible disorders.

*Natural action
in the animal
body.*

10. Hence we may perhaps deduce the reason, why the author of nature has made nearly all the aliments of animals incline to acidity; for, the acid salts on this account, predominating in the stomach, easier dispose such aliments to dissolve, whose firmer parts cohere principally by means of earth; whence they would otherwise much more difficultly be dissolv'd into fluid chyle. But when afterwards a matter is to be form'd of this chyle, fit to bind the solids together, the tendency to acidity, which was necessary in the chyle, is changed, and an alkaline tendency of the salts introduced; which, by binding the earthy particles, forms a structure indissoluble in water, and fit to resist the action of the fluids. At least, we know that bones remain solid and firm, if steep'd in alkalies; but grow soft and flexible, if detain'd in acids:

acids: as the ingenious Mr. *Rayss* has often assured me, he found in his anatomical experiments. And, doubtless, when the power of changing acerbities into alkalies is wanting in the body, the bones, cartilages, teeth, and ligaments, become soft, weak, loose, and flexible; as we daily see in the rickets. Hence, physicians and surgeons should be cautious, how they apply strong acids to the bones and teeth; such acids, used in the way of dentifrice, with design to render the teeth white and glossy, may soon render the person melancholy, nervous or paralytic: it is doubtless much better to use, for this purpose, the milder fix'd alkalies, or alkaline solutions well diluted with water; whereby the earthy part of the teeth will remain unhurt.

11. These sulphurs do not of themselves dissolve in water, but readily unite therewith after being intimately mixed with alkalies: whence we may easily understand the medicinal virtues of the sulphureous mineral waters. Volatile alkaline salts will also dissolve sulphurs, and render them miscible with water; so that we see, water, by the assistance of alkalies, becomes an excellent solvent of sulphurs. And as this is applicable even to the sulphurs which lie concealed in metals and semi-metals; hence we have a way of manifesting and producing to view such sulphurs, as before lay hid; by which means, slight productions have been sold at high prices, as great secrets, to unskillful purchasers: and thus even princes themselves have been often imposed upon. I have seen a liquor, prepared from antimony, sold under the specious title of a *Panacea*; a few drops whereof, taken in wine, were said to cure diseases speedily, without any sensible effect; and indeed they did service in some distempers: but secrets, once discovered, are apt to be despised, when they are to be had cheap, without the disguise of a mystery. Thus, upon examination, I easily discovered this liquor was prepared from taking levigated antimony, by putting twice its quantity of *oleum tartari per deliquium* thereto, and digesting them in a sand-heat together; whereby the liquid alkali, dissolving in the sulphur of the antimony, thus extracts a red tincture, of a fiery taste, and an alkaline, heating, aperitive, diuretic, and diaphoretic virtue. But, to say the truth, as good a medicine may presently be procured by boiling common sulphur in an alkaline lixivium: as the sulphur of antimony does not differ from common brimstone; and as the alkali does not dissolve the metallic part of the antimony. In like manner, by digesting powdered antimony with the alkaline spirit of sal-ammoniac, a golden sulphureous tincture may be obtained; and as good an one from common sulphur, as Mr. *Boyle* has shewn. But there is no end of deceit and imposition in this way people delighting in being deceived, and some of the rich, in thus throwing away their money; whilst there is no end to the avarice and boasting of the pretenders to secrets in physic.

12. Such bodies also, as consist of a glutinous, viscous, or hard substance, *Resins.* and therefore remain untouched by water, may yet be rendered perfectly soluble therein; by first uniting them intimately with fixed or volatile alkalies. Thus we find putrescent urine, salt of tartar, soap, gall, honey, sugar, yolk of eggs, &c. being mixed with these tenacious bodies, render them commodiously dissolvable in water; which hence generally acquires a deterging, cleansing power.

power. Oils, balsams, rosins, gums, &c. by this treatment, become miscible with water. And thus I have explained the principal effects of water, as a solvent upon all the kinds of bodies suited thereto; and two which all others may be referred.

*Aqueous sol-
vents.*

13. Having explained the dissolving power of water, we need not be large upon aqueous menstrooms, which would lead us to a repetition of what is above related; I shall here therefore only add a few remarkable particulars: and, (1.) Hail, collected in the summer-time, after a series of hot weather, and thunder consequent thereon, being kept in clean vessels, has a different effect from all other water; perhaps on account of being purer, carried higher into the atmosphere, and froze there before it fell lower. (2.) Next to this in purity, we reckon snow-water, collected in a cold winter, in a still air, and a high sandy desert place, and from the upper part of a deep drift. (3.) Dew being a mixture of aqueous, spirituous, saline and unctuous vapours, and of all sorts of dry exhalations, differs greatly from all other aqueous menstrooms; so that the effects of dew can scarce be determined, or brought under one class. Whence it is no wonder, that many have thought the matter of the universal salt was concealed therein; and that a saline substance, which they call the congealed spirit of the universe, might be extracted from it. But it is time to proceed to the other kind of menstrooms; only first observing, that water floating in the air, may often act as a menstruum, and the action be falsely ascribed to the power of the air.

S E C T. IV.

Of OILS, and OILY MENSTRUUMS.

Oils.

1. **O**IL, considered as a menstruum, is a fluid juice, (or capable of being rendered fluid with a small degree of heat) unctuous, burning in the fire, and immiscible with water. Alcohol is excluded from the class of oils, by its being easily miscible with water; whilst in other properties it has a perfect resemblance to them. All the oils we know are either native, as they exist in bodies, or are obtain'd from them by art, especially by chemistry; which always alters their nature: and every one must make this difference, as we find it real from the difference of their efficacy in the way of solvents. Native oils therefore are every where found in fossils, vegetables, and animals; and these oils are changed by art, upon boiling unctuous bodies in water, so as to melt the fat, and extract it from its lodgment: whence, by its lightness, it floats upon the surface of the water, and may be skimmed off without much changing its nature. Another way of obtaining it is by expression; when, the oily subject being bruised, it is squeezed betwixt iron-plates in a strong press, and the oil forced out. Whence, if too much heat be not used in the pressing, the oil here also is but little changed. Sometimes a close fire is used for the purpose; so as to scorch the oily subject, and melt the oil away from it; as in the obtaining of pitch and tar, from

from the loppings of fir, &c. Lastly, oils are obtained by distillation in the alembic, with water, *per ascensum*; and by the retort, or *per descensum*, when the fire is placed above the subject.

2. It is remarkable of these distilled oils, that scarce any of them congeal, *Not concreting.* but remain fluid in the greatest natural cold; whereas most of the oils by expression congeal, with strong cold, into a mass, consisting of little globules united; as we see in oil-olive, rape-oil, &c. Whilst others of them, as linseed-oil, do not freeze in the keenest frost. I have frequently considered this remarkable difference in oils, without being able to discover whereon it depends. Their dissolving power is not exerted, unless they be in a fluid form; and as some of them freeze sooner than water, their dissolving power is less durable, with respect to cold, than that of water; but those which remain fluid in all the degrees of natural cold, constantly retain and preserve their power of dissolving. Whence it appears not easy to fix a common point of heat in nature, at which the dissolving power of oils begins; tho' it may be nearly limited in any one species of oil, after it is once accurately observed. And here it may appear surprizing, that though linseed-oil remains fluid in the severest frost; yet, upon examination, it is then no hotter than ice, or any other congealed oil.

3. When oil is heated by a gradual, well-regulated fire, it does not boil *Hold much fire.* with 212 degrees of heat, as water does; but grows constantly hotter by the same fire without boiling, till the heat rises to 600 degrees: whence we see why boiling oil is so much hotter, and more scalding, than boiling water. But all oils do not boil with the same heat; the lightest and most subtil boil the soonest, and with the least heat: whereas others boil slower, and receive more fire before they will boil. Thus, rectified oil of turpentine boils soon, but oil of linseed late. Where we see the difficulty there is to determine the dissolving power of oil; because in linseed-oil, for example, this power begins with the greatest degree of natural cold, from whence it increases up to 600 degrees, and in each degree of increase constantly acquires a new power of acting; whether it be upon the same body in different degrees of heat, or upon different bodies, in the same or different degrees: in both which respects the scale is infinite.

4. To illustrate this, take three equal phials, of the same figure and height, *Shewn by experiments.* fill one with alcohol, the second with oil of turpentine, and the third with oil-olive; put them into a copper of pure rain-water, along with *Fahrenheit's* mercurial thermometer; then lighting the fire, and keeping the water stirring, that it may heat equably; when the water comes to be a hundred seventy five degrees hot, the alcohol will boil strongly: this phial therefore being taken out, and the water being farther heated to 213 degrees; this also will boil, and the mercury in the thermometer expand no more, how strong soever the fire be made. At the same time, neither the oil of turpentine, nor the oil-olive will boil at all. Whence we perceive this remarkable difference, that alcohol, tho' it be an attenuated, inflammable oil, boils much sooner than water; and that oil of turpentine, though much lighter than water, and considerably thin and inflammable, does not boil when the water does; any more than oil-olive. Whence neither inflammability, nor levi-

ty, nor volatility, is here the cause; since oil of turpentine is so volatile, as to rise with boiling water in distillation.

5. Again, the apparatus being the same, only a brine of sea-salt, made as strong as possible by boiling, being used instead of the water; you will find, that when the thermometer stands at 175, the alcohol again will boil; when the thermometer rises to 218 degrees, the brine will boil; but the thermometer will now rise gradually; because, by the strong boiling of the brine, water is discharged, and the liquor made stronger; but still the oil of turpentine, and oil-olive, will shew no sign of boiling.

6. The following experiment should be made with care. Fill two thirds of a small long-necked phial, of an equal thickness, with oil of turpentine; heat the whole glass gently, to prevent its cracking; then set it over a clear soft fire, to be increased by degrees; it will thus be long before the oil comes to boil; but at length it will boil strongly with a great crackling, and continue boiling thus violently, long after it is removed from the fire; whereas alcohol ceases to boil, as soon as the containing phial is taken from the fire; and so does water presently after. To discover the degree of heat in this oil before it boil, put some linseed-oil into a copper-vessel, and set it upon a naked fire; place a mercurial thermometer therein, along with the phial of oil of turpentine; which will be found to boil much sooner than the linseed-oil; whilst the thermometer shews the degree of heat. But as these oils, by boiling, throw off their more volatile parts, and leave the remainder thicker, they now require more heat, every moment, to keep them boiling. Whence physicians need not wonder, that these oils, rendered thick by boiling, heat the body so violently; which I take to be an useful observation.

7. In the same manner, if a glass-phial of fresh-drawn oil of almonds be set upon a naked fire, and continued there, so as not to melt the glass; this oil will then boil with a quiet equable motion, in a heat of above 600 degrees.

*How much
fire may be
contained in
oil.*

8. Having thus seen that oil will receive almost thrice as much fire as water, we may hence easily understand that the dissolving power of oil, which power in menstruums depends upon fire, must be much greater in oil than in water: for, since many oils remain fluid in the first degree of the thermometer, whereas water freezes at about the thirty third; and since the scale of heat in water, while it remains fluid, is but 180 degrees, (its freezing point being 33, and its boiling heat 213;) and since the scale of heat in linseed-oil is at least up to 600; it follows, that the power of heat in this oil, is to the power of heat in water, as ten to three: which could scarce have been discovered *a priori*. And considering that many oils, inspissated by boiling, may thus receive much more fire; hence the scale of the power of heat may be still farther extended in such oils.

*The effect of
oil upon ani-
mals and ve-
getables.*

9. It is found, by experience, that the bodies of animals, and all their parts, as also of vegetables, are kept from dissipating, fermenting, putrefying, and changing, by being carefully plunged in oil; and this for ever so long a time, even in the hottest climate. Insects likewise, which are apt to prey upon and destroy bodies, are prevented from doing it, when covered with oil; as being kept intire, whilst they remain buried therein. And after these bodies have remained covered with oil for a proper season, so

as to be thoroughly impregnated therewith, they seem to become almost incorruptible; at least they are capable of thus being long preserved; as appears from carcases treated in this manner: upon which discovery the art of embalming principally depends; the origin and efficacy whereof is hence manifest.

10. If bodies are suddenly plunged into boiling oil, they presently acquire a hard and almost stony coat, of the colour which usually appears in bodies scorched by a naked fire; viz. yellow, red, or black; whilst the inner substance, being agitated by the great heat of the boiling oil, is wonderfully changed, digested, and ripened; till at length the whole is consolidated, and rendered durable for great lengths of time. But when these bodies abound with aqueous juices, as in flesh or fish, dried only on the surface; these juices, contained within the external crust, being thus more than boiled, become surprisingly soft, roscid, digestible, and nutrimental. And food, thus treated, may be preserved for a long time; as all the principles of bodies so prepared, being intimately united, perfect one another, and turn to a substance that is well defended from the action of external causes.

The effects of boiling oil upon them.

11. Hence we may draw some unexpected consequences; as, (1.) That the degrees of heat, received by bodies from fire, are not in proportion to the densities of the heated bodies. (2.) And yet, that in the same bodies, gradually rendered more dense, more fire may be communicated in proportion to the increase of their density. (3.) That the power of receiving a greater degree of heat does not depend upon the bodies being combustible in the fire: thus alcohol being brought to boil, does not receive more fire, or heat; tho' nothing in nature is more combustible; nor does any known liquor receive less fire. Whence again we see, it is in vain to seek after general properties in chemistry; but we are to discover the particular properties of bodies by particular experiments. (4.) That some metals may be intimately dissolved in some oils by boiling; so as thence to form a mixture not easily resolved into its principles: and, by this means, many noble discoveries have been made for mechanical and medical purposes.

Consequences.

12. Thus, for example, put half an ounce of red-lead into a long-necked phial, and pour to it an ounce and a half of oil-olive, and shake them well together; heat the glass carefully, then set it over the fire, so as almost to touch the coals, and bring the oil to boil: upon which, the red-lead will dissolve, and mix and unite into a mass therewith, when the oil has acquired a great degree of heat: and thus a metallic balsam, or an excellent cement for water-works, may be prepared. The same experiment will succeed, if made with granulated lead; the lead first melting at the bottom, even before the oil begins to boil, or fume. Whence we see, that lead is more easily melted than glass; and that oil cannot be made to dissolve glass, with any degree of heat the oil will receive: and hence we see the reason, why melted lead scalds less than boiling oil, and may be nimbly handled; if the skin be first rubbed over with dry chalk. This experiment might prove dangerous, if a drop of water should fall into the glass; or any aqueous vapour arise from the boiling oil, and fall back upon the boiling matter. The same experiment also succeeds with tin, and a mixture of tin and lead; the solution

Lead dissolved in oil.

whereof together, is quicker performed than of either alone. Hence again, we may draw farther consequences; as, (1.) That oils receive, and long retain much fire before they boil. (2.) That no fluid in nature receives more fire than oil: for all lixiviums, and oil of vitriol it self, boil sooner, and prove less hot upon boiling: even quicksilver it self boils rather sooner, or nearly about the same time. (3.) That a great force of fire must act upon oils, before they rise in vapour. (4.) That oils communicate the same force of fire they receive, to the vessels in which they are boiled: whence, tho' water may be boiled in vessels of tin or lead, yet oil cannot. (5.) That the same force of fire, received by the oils, is communicated to the metals contained therein. (6.) That we cannot easily find a way of communicating more fire to oil than by boiling it; for if we would endeavour to make oil collect more fire, we must find a way of compressing the oil in the containing vessel, with a greater weight than that of the atmosphere; whereby indeed heat might be increased in proportion, as we shewed in the chapter of air and water. Whence it appears that oil, compressed by the increased weight of the atmosphere, at great depths in the earth, may acquire a most violent heat, if it should there meet with a strong fire; when, if water should happen to touch the oil in this state, it might occasion most terrible earthquakes: which may possibly be one physical cause of *Vulcano's*. (7.) Oils, whilst they remain fluid, will not permit more heat to be communicated to the containing vessel than to themselves; and therefore prevent all vessels from melting, which will not fuse with less than 600 degrees of heat. (8.) Hence the author of nature has set a limit to fire; which limit checks its power upon the most inflammable matter we know.

Oils act by means of their own water, and acid.

13. In order to explain the dissolving power of oils, we must remember, that every express'd, crude, vegetable oil, constantly contains water; as may easily appear upon boiling express'd oil of almonds in chemical glasses; whereby an aqueous vapour is raised, and condensing in the neck of the vessel, forms visible drops, which falling back upon the boiling oil, occasion great commotion and crackling. Hence, oils act in their dissolving capacity, by means of this latent water, according to the degree of fire applied; whilst the crackling and commotion, thus occasioned in the boiling, may in some degree affect the manner of solution: and hence, also, after this water is discharged by long boiling, the property of oil, as a menstruum, is changed; for oils that have long been boiled, dissolve bodies differently from what they do when crude.

14. But, besides this water, oils contain a certain subtle, latent salt, supposed to be very penetrating, and which is generally acid, and volatile; as in some of them is manifest by the smell. These salts appear in the form of acid spirits, collecting themselves like water, and separating from the oil, so as not to be again easily mixed therewith; tho' it is not easy to free the oil perfectly from its acid: for, if the native oils, or turpentine of the pine, or fir, be distilled with degrees of fire, an acid spirit always rises, during the whole distillation; but, in the greatest quantity at first: and the same holds, in some degree, of most other oils.

15. When,

15. When, therefore, chemists would ascertain the dissolving power of oil, they should carefully distinguish whether the effect be owing to the water and acid they contain; otherwise great errors might arise: for, we see in painting, that colours dissolved in oil, which has been boiled, unite and sink in better, dry quicker, and remain more beautiful, than when mixed up with crude oil. And thus, also, the particular power, which the softest oils are supposed to have of dissolving metals, in a gentle heat, seems principally owing to the latent acid; and not to the oily part: it having been observed, that oil-olive, when mixed with very fine filings of iron, copper, or lead, and long digested together, a part of the metal is thus taken up by the oil, so as to give it a new colour, and extraordinary properties: hence, the power of oil as a solvent, has been extended too far; for, this power does not remain in oils, after they have been long boiled, and are deprived of their latent acid. Hence, the polishers of brass, and copper, have observed, that their work cannot be well preserved from rust and tarnish, by rubbing it over with crude oil; but much better, by besmearing it with boiled oil; especially, if a little ceruss, or black-lead be added in the boiling, so as perfectly to imbibe this acid: by which means, an excellent unction is obtained, for preserving the polish, and edge of such metallic vessels and instruments. Dr. Hoffman (a) has shewn by experiment, that, even distilled oils contain an acid; for, by grinding the distilled oils of lavender, and of turpentine, with salt of tartar, he thence obtained a neutral salt. So, likewise, a gentle distillation separates these salts from such oils: for, thus the oil of turpentine, and of juniper, will afford an acid liquor.

16. Those oils which are obtained by distillation, from alkaline, or putrefied vegetable, or animal substances, abound with volatile alkaline salts; which may be copiously separated from them, by a gentle fire, in a white solid form: whenever, therefore, we would explain the properties of oils, we should carefully separate them from all foreign salts, and examine them pure; otherwise we can never form a right judgment of their virtues.

Sometimes,
contain vo-
latile alkali.

17. But here it is necessary, before we consider oils farther, in the way of menstruums, to examine how long they may remain in an oily state; and with regard to this, there are several remarkable particulars: for, oils obtained by distillation with water, or without water by the retort, constantly leave earth behind them, upon being re-distilled to dryness in close vessels; and gradually become more subtile, less adhesive, more fluid and transparent: and when re-distilled fourteen times or more, they each time become different oils, and leave an earth behind them; so as, thus, at length to become penetrating anodyne medicines, excellent in many obstinate distempers: and each time, also, they make a different menstruum: whence the elder Helmont imagined that the oils of human blood, thus distilled several times with spirits of salt, till no faeces were left behind, would prove a diaphoretic medicine, capable of dissolving, like a menstruum, all præternatural, and otherwise mortal obstructions, and coagulations, in the body (b). The excellent Dr. Hoffman (c) assures us, he has prepared oils in this manner,

Simple oils.

(a) Obs. Phys. Chem. p. 56, 57.

(c) Obs. Phys. Chem. p. 59.

(b) See Helmont. Auror. med. Belg. p. 188.

*The presiding
spirit in oils.*

and gives a high commendation of their medicinal virtue : and another less faithful writer affirms, that the universal remedy may be obtained by means of an oil prepared in this manner. The ancient chemists have described these oils some ages ago ; and doubtless, menstruums may, hence, be procured of an almost inimitable dissolving virtue : upon which subject, *Raymond Lully*, and *Isaac Hollandus*, have left us large processes, which may deserve to be consulted. All kinds of oils have a certain subtle, volatile substance adhering to them, and separable from them, called by the name of their presiding spirit ; which is a moveable, odorous, high-tasted thing, produced by fire, and the true cause of very great effects. This spirit being innate in oils, detained and confined in them, communicates thereto a singular efficacious virtue, no where else to be found ; and, when it intirely quits the oils, it leaves them sluggish and unactive, so as to be scarce distinguishable from one another : and as it spontaneously exhales from many of these oils, with a gentle heat, it mixes with the air, and leaves them insipid, and unactive ; so as to render them incapable of performing what they did before. Their dissolving power seems chiefly owing to this, that oils are disposed to receive much fire into themselves, and apply it to other bodies.

*The bodies dis-
solvable in
true oils.*

18. (1.) Most oils mix with other oils, tho' some of them not easily ; as in the distillation of turpentine and amber ; where the oils, raised by different degrees of fire, are different in weight, consistence, colour, and situation, so as not readily to unite with each other. (2.) True resinous bodies melt and dissolve in oils. (3.) So do many of the gums, especially such as have a mixture of rosin. (4.) So, likewise, do condensed oils or balsams. (5.) So do sulphurs, both the native and artificial, and both the liquid and solid ; and this, tho' concealed in other bodies. Thus antimony, finely powdered, or sublimed into flowers, being boiled with oil, soon affords a thick red balsam of antimony ; tho' it proceeds only from the sulphur of the antimony, dissolved by the oil, which leaves the metallic part untouched : and the same holds also of other semi-metals, abounding with sulphur.

SECT. V.

Of ALCOHOL, or Spirituous MENSTRUUMS properly so called.

*Alcohol a se-
cret men-
struum.*

1. **T**HE alchemists, or those called the adepts, are large upon the subject of spirit of wine ; which, when reduced to its highest subtilty, they employed in the preparation of all their other secret menstruums ; as appears in the *Circulatum of Paracelsus* : whence the industrious *Weidenfeld* is of opinion, that the adepts have clearly described all their secrets, but only concealed their philosophic spirit of wine ; which, being once known, all the rest would be intelligible. The justness of this opinion may be doubted ; but it is easy to show, that the spirit of wine, which the adepts have described by its particular marks, is the same that we are possess'd of ; as appears from its subtilty, volatility, manner of preparing, fragrance, running veiny in distillation,

stillation, total inflammability, firing linen when burnt thereon, uniting with salt of tartar, making the *offa Helmontiana*, extracting a subtile sulphur from animals, vegetables, and minerals, its preserving virtue, preventing putrefaction, &c. It is true, other properties are assigned it by the adepts, not to be found in our alcohol; as particularly, its power of dissolving salts: but it may be doubted, whether this arises from mistaking the spirit, or from not knowing the requisite, secret preparation of these salts; wherein something wonderful often lies concealed.

2. Eminent chemists have asserted in their writings, that alcohol could not be united with a pure fixed alkali: and this is no wonder, as the effect may be prevented by the least aqueous moisture in either the salt, or the alcohol. But, if pure alcohol be applied to perfectly dry salt of tartar, a rich tincture is immediately extracted, and a true combination made. Hence, we cannot be too inquisitive into the nature of this liquor, which, on account of its excellence, we esteem the first among the spirituous menstrooms. May unite with fixed alkali.

3. This alcohol is procured from vegetables alone, by bare fermentation, and repeated distillation: it is best obtained from wine, mead, or beer: for, tho' these liquors may quench fire, yet the spirit obtained from them by distillation, is inflammable: and, when all water is perfectly separated from this spirit, we obtain pure and perfect alcohol; which, therefore, in almost every respect seems to be an extremely subtile, vegetable oil: tho' in its gross state, its parts are strongly attractive of one another; so as to make it form into drops, and not mix with water: but, when turned into alcohol, these parts lose both of their attractive and repulsive power; whence, oil is called alcohol, when it mixes with water, and is totally inflammable. Animal, and vegetable substances, when perfectly putrefied, may have their oils so subtilized and volatilized, as to be inflammable in the open air; and by repeated distillation, such oils may be so attenuated, as almost to mix with water. When, therefore, the dissolving power of these spirits is to be determined, we must, first, regard what kind of spirit it is: for common brandy contains much water, a liquid acid volatile salt, a disagreeable oil, and alcohol; rectified spirit of wine contains less water, less of the nauseous oil, a volatile acid spirit, as before, and mere alcohol. Perfect alcohol, prepared without addition, contains neither water, acid nor gross oil; and if once gently drawn off from fixed alkali, by distillation, it becomes highly purified: and as there are these differences in this spirit, we are carefully to regard them. How prepared.

4. (1.) Perfectly pure alcohol dissolves water, and all aqueous liquors. The bodies it dissolves. (2.) And, consequently, wines of all kinds. (3.) It dissolves all spirituous fermenting acids; as the tribe of vinegars. (4.) All pure oils. (5.) All true vegetable rosins. (6.) Most of the gummy rosins. (7.) Pure volatile, alkaline salts. (8.) Perfectly dry and fixed alkaline salts. (9.) Most of the soaps. (10.) Sulphurs, first opened and dissolved by alkalies; but it does not touch compound or native salts; as, sal-ammoniac, sea-salt, nitre, &c. nor pure earth, pure sulphur, mercury, metals, semi-metals, nor stones, whether vulgar or precious.

S E C T. VI.

Of the alkaline, and acid spirituous MENSTRUUMS.

*Ambiguity of
the word spi-
rit.*

1. **M**OST chemists, under oily and spirituous menstrooms, have ranged two kinds, which might rather be termed saline or compound. This happens, because these menstrooms usually appear in an unctuous form; and are generally not only volatile, but liquid and subtile: whence, some acids, and some alkalies have been called by the name of spirits, on account of their subtile, volatile, and unctuous appearance; tho' they differ greatly from each other, not only in kind, or as to acid and alkali, but also, acid from acid, and alkaline from alkaline spirit. We, therefore, first, divide the saline spirituous menstrooms into the acid and alkaline tribes; this distinction being absolutely necessary. Next, we divide the alkaline spirits from one another; some of them being simple, and others compound. The simplest of these consist of water, and an extremely subtile, volatile, alkaline salt, both together appearing in the form of a thin, pellucid, and somewhat unctuous liquor; as the pure alkaline spirit of sal-ammoniac; and to this class, belong the numerous alkaline spirits obtained both from animals and vegetables, after being deprived of the oil that is apt to adhere thereto; as we daily see practised by the chemists, who can thus produce them from the hot, antiscorbutic plants, putrefied vegetables, and all animal substances. The more compound kind, usually consist of water, the volatile salt just mentioned, and a fetid oil; into which three parts they may be separated; and, therefore, are a kind of volatile alkaline soap, diluted in a proportion of water barely sufficient to dissolve it. The acid, and commonly volatile liquors, are also called spirits, by the chemists, for the reason above-assigned; but all these, when examined, prove to be acid salts dissolved in pure water. Thus, oil of vitriol, and *oleum sulphuris per campanam*, several times distilled with boiling water, become in a great measure volatile. Upon this consideration, therefore, I shall here drop the name of spirits; and for the future, call them by the name of saline menstrooms.

S E C T. VII.

Of the simple, saline MENSTRUUMS.

*Salts neces-
sary to be
known.*

1. **I**T is a saying of the alchemists, that such as do not understand salts can never arrive at the grand secrets; and no wonder, as various salts have great energy in the dissolving of bodies: thus, if we may credit the sublimer artists, that famous solvent, called the *Circulatum*, is said to have been made by *Paracelsus*, from sea-salt? Thus much is certain, that salts

salts have an exceedingly great power, in the whole business of menstruums; whence I have bestowed no small pains thereon.

2. I call salt a body which dissolves in water, and, if not volatile, fuses in the fire, and, having a sapid taste. When a salt is pure, or either naturally, or artificially separated from every thing else, it consists of particles too minute to be distinctly and separately viewed, even by the help of the best glasses; so that we can pronounce nothing as to the figure of these particles. And, when saline bodies are resolved into the ultimate particles, from whence they are formed, they thus seem to become perfectly volatile; so as, when separated from each other, and from all foreign substances, to fly off into the air: as we shewed by experiment in the chapter of earth. Therefore, when these last particles of pure salt concrete into sensible clusters, they always are held together by some intermediate particles; particularly those of water and earth, which here serve for a cement, and make the association permanent. Hence, we see, that as the original particles of salt can scarce ever be confined in vessels; so, we can say little of their chemical actions: but, when they appear in a stable form, we may have some certainty of them in this compound state.

3. We must next consider the principal differences of salt, arising chiefly from the different saline principles of which they are composed: and tho' these principles are separately unknown; yet, doubtless, they have a certain peculiar property respectively. A second difference arises from the other principle, which uniting with the saline one constitutes the salt. We, therefore, divide all kind of salts, into, such as differ, either in respect of their saline principle, their connecting principle, or both. And with regard to the first division; I distinguish salts, and saline menstruums, into the following classes; viz. (1.) Fixed alcalies. (2.) Volatile alcalies. (3.) Native vegetable acids. (4.) Fermenting vegetable acids. (5.) Fermented vegetable acids. (6.) Vegetable acids obtained upon burning. (7.) Vegetable acids procured by distillation. (8.) Native fossil acids. (9.) Fossil acids procured by burning. (10.) Fossil acids procured by distillation. (11.) Neutral acid salts; as, borax, nitre, pit-salt, sal-gem, sea-salt, and sal-ammoniac. (12.) Other salts composed of these simple ones. Each of which salts should be examined, in order to find out their peculiar properties; whereby we may come to a true knowledge of them, so far as regards the dissolving of bodies.

S E C T. VIII.

Of fixed Alkali as a MENSTRUUM.

1. THE Oriental and Egyptian word, *Kali*, denotes a certain plant abounding with salt, and growing upon the sea-shores, and banks of the Nile, and the Syrian river *Belus*, as *Pliny* relates from ancient authors. This plant being burnt, in its perfection, affords ashes of a remarkable sharp saline taste; and if these ashes be boiled in water, they make a strong lixivium, which upon standing deposits its earthy part, as being incapable

of dissolving in water, or burning in the fire. This lixivium being boiled in an iron-vessel, to perfect dryness, leaves a white solid mass behind it, perfectly dissolvable in water, and of a high caustic taste: whence, from the manner of preparation, the salts of this kind, are called lixivial, or more commonly, alkaline salts; and sometimes, also, by the name of *rochetta*, or *soda*. This kind of salt makes frit, with any stony matter capable of striking fire with steel; and of this frit, glass is prepared. When rendered sharper by quick-lime, this salt makes the soap-boiler's lee, which, when boiled with fat, or oil, constitutes soap. The best kind comes to us from *Egypt*, or *Alexandria*, and *Tripoly*. Now, as all our physical knowledge is originally derived from the sensible properties we find in bodies; so, all the differences of bodies are to be derived from the sensible marks we find in them; nor, have we any other way to come at the knowledge of bodies: we shall, therefore, here lay down, the chemical and physical marks of alkali.

Its marks.

2. (1.) This alkali, therefore, is of vegetable extraction. (2.) It is always obtained by means of burning the plant to ashes. (3.) It is of a fixed nature, so as to remain long in the fire. (4.) It dissolves in a moist air, and, thus, lets fall a sediment: and cannot long be kept dry, tho' ever so carefully stopt down and secured. (5.) It gives the sensation of a burning, fiery acrimony to the tongue; at the same time tasting like urine: whence, these salts are sometimes, tho' improperly, called urinous: for the proper taste of this alkali is not urinous at first; but, after being held some time in the mouth, and solliciting the saliva by its acrimony; the neutral animal salts, naturally contained in the saliva, deposite all their acid in the alkali; whence, the other part of these neutral salts, now, deprived of their fixing acid, becomes volatile, alkaline, and urinous: and, this is the true cause of the urinous taste, attributed to these salts. (6.) This salt, when perfectly clear of all foreign mixture, is scentless and fixed in the fire; but, being highly attractive of all acids; as soon as ever it touches any substance, containing a volatile, alkaline salt, detained by an acid, the alkali immediately absorbs this acid, lets loose the latent, volatile alkaline salt, and leaves it to its own volatile, pungent nature: so that, tho' this volatile alkaline salt could not be discovered by the smell in the subject before; it, now, plainly may; and is not the smell of the fixed alkali, but of the volatile one. Thus, if a fixed alkaline salt be put to fresh, warm urine, it instantly discovers an alkaline smell, which it had not before. (7.) It is another property of fixed alkali, that it immediately makes an ebullition upon mixing with any acid, and intimately unites into one substance therewith: so that, if the point of saturation be exactly hit, no sign, either of an acid, or an alkali, is discoverable, so long as the two remain in a compound state; but they thus produce a fluid substance, called by the name of neutral. (8.) If pure, fixed alkali be mixed with the juices of turnsol, roses, or violets, it presently changes their natural colours to a green. (9.) If applied, for some time, to the warm and moist human skin, it raises an inflammation, and causes an eschar, after the manner of a sphacelation. (10.) All these salts have a highly deterfive power, or cleansing virtue, not to be found in neutral salts. And by these marks,

marks, fixed alkaline salts may be known and distinguished from all others, so as to avoid confusion in the history of menstrooms.

3. The like fixed alkaline salts may be also obtained from any crude, recent, vegetable burnt to ashes, and treated in the same manner as we have mentioned of kali; tho' some vegetables afford but a small proportion, particularly those which have a pungent smell, and make the eyes water; the saline part being, here, almost totally volatile, and going off, in the burning; as garlic, scurvy-grass, onions, water-creffes, squills, radish, mustard, &c. wherein the salts, by nature, are rendered as alkaline and volatile, as in animal substances. *The origin.*

4. These lixivious salts were well known to the ancients in almost every age: as, being mentioned by *Aristotle, Varro, Pliny, &c* (d): but no natural salt, that I know of, hath hitherto been found with the marks above-mentioned: all of them being produced from vegetable subjects, by the bare action of the fire. And no vegetable could at any time be burnt to ashes, but these salts were produced: so that, in all times and places, large quantities of this salt must have been made upon the surface of the earth, with the ashes; and, thus these saline ashes being washed into the ground, may have rendered it fruitful in many places: tho' their alkaline nature is soon changed, and a new form assumed, by which they afterwards act.

5. It must here be remarked, that no vegetables could at any time afford this salt without burning; for, if suffered to dry or rot spontaneously, they vanish, or change their form, without leaving the least fixed alkali behind, and are thus dissipated in fine, insensible volatile particles; whilst only a mere terrestrial matter remains. It is therefore universal, and confirmed by the experience of all ages, that nature employs no fixed alkali in forming either the fluid, or solid parts of vegetables. Whence, again, we conclude, that fixed alkali is not made by the operation of nature; but, by the action of fire. This is farther confirmed from hence, that those vegetables, which, when burnt, would afford much fixed alkali, being once thoroughly putrefied, become in great measure volatile; so as, if they were now to be burnt with an open fire, they would afford no fixed salt at all; and leave nothing behind, but white, insipid, terrestrial ashes, containing no salt: fixed salt, therefore, seems as much a creature of the fire, as glass. *Not yielded spontaneously from plants.*

6. We shall, hereafter, see that these fixed alkaline salts, easily resolve into a large proportion of a hard, bitter, saline, and almost vitrified substance, a simple earth; and a purer and stronger fixed alkali: whence it appears, that these salts are not simple bodies, but composed of different ones; whilst the seemingly homogeneous union of these principles into one substance, is owing to a strong fire. Hence it will follow, that nature, so far as we at present understand her procedure, never acts by means of fixed alkaline salts as her own instruments; but, only, as she receives them first prepared by fire: and, when she uses them at all, she operates with them, as they are compounded of the three principles just mentioned; to which we may add a fourth, viz. an oily matter, always adhering thereto, as appears from many experiments. *Not a simple body.*

Y y y 2

(d) See *Aristot. Meteor. xi. c. 3. Varro, de re rust. L. i. c. 7. Plin. L. xvii. c. 28. L. xiv. c. 26. L. xvi. c. 11. L. xxxvi. c. 69.*

Its differences.

7. Hence, also, it appears that the more these fixed alkaline salts are separated from their other principles, the more they differ from one another; since the remaining salt will thus become more simple, and, consequently, differ in its manner of acting. Thus, for example, pot-ash, which contains an excellent fixed alkali, also contains a large proportion of a hard bitter transparent salt, not easily dissolvable in water: and this salt being carefully separated, the alkali, thus, becomes much purer, and fitter for many purposes as an alkali, than it would have been if that salt had remained in it. We must also observe, that these alkaline salts are often strangely changed, by the falling in, or admixture of any fix'd foreign body during the burning; as it may thus unite with the salt: thus, for example, if nitre should mix with the ashes, and be fixed with the other salt of the vegetable, it would make an alkali that would afford the fume and smell of spirit of nitre, upon pouring oil of vitriol to such an adulterated salt; a thing that never happens in pure alkali: and the same holds true of sea-salt, &c. It must also be observed, that different salts are produced, according to the different manner wherein the vegetables are burnt: thus, we find a vegetable burnt with a quick and strong fire, affords a different salt from what it would do if burnt slow, with a stifled heat: as we see in preparing the salts of *Tachenus*.

*Its kinds,**viz.**Pot-ash.*

8. We next proceed to enumerate the several kinds of fixed alkali commonly used in chemistry. And, here, the commonest kind of all, is that called by the name of pot-ash; imported to us, in large casks, from the north; particularly from *Russia*, where they make it, by burning the green wood of fir, pine, oak, &c.

How made.

9. The way of making it, is, by piling up large heaps of cut wood, in pits dug in the ground, setting them on fire and burning them to ashes, which they afterwards sift, before they grow cold; then they boil these ashes in water to dissolve out the salt, and suffering the liquor to rest, they pour it off clear, and boil it in large copper pots, for three days, till it comes to a dry salt; called pot-ash, from the pots it is boiled in: this salt is put, whilst hot and dry, into casks perfectly free from aqueous moisture and oil, so that it may be kept close; otherwise it would run in a moist air, like salt of tartar *per deliquium*, and afford a terrestrial sediment: in which manner, I have at one operation obtained six drams of fæces from a pound of salt. When this salt is gradually dissolved by putting hot water to it, then suffered to rest, the clear liquor being poured off and filtered, then evaporated to a half in clean glasses, and set in a cold, still place, it soon shoots to the sides of the glass, hard, figured, pellucid crystals, that do not run, even in a moist air, and difficultly dissolve in water; but are brittle like glass, bitter to the taste, and resembling sandiver, or the salt thrown up in the making of glass. This bitter salt, therefore, is of a particular nature; and may thus be procured in a considerably large proportion. After this operation, four scruples of a terrestrial matter will fall to the bottom, from a pound of this salt; thus leaving the remaining fixed alkali considerably pure: so that, the liquor being now evaporated to dryness, affords a white, fixed alkaline salt, fit for making fine glass with clean sand.

10. If this purified salt be exposed to a violent fire, it thus melts and becomes stronger; and if now put in a glass-dish, and set in the open air, it again runs *per deliquium*, and deposits fresh fæces; so that by repeating these operations, the original salt either becomes volatile, or resolves itself into a part that flies off insensibly, a neutral salt, and a terrestrial substance, and loses all its acrimony. And it frequently happens, upon repeating this operation, that the alcali changes its nature, and turns into a neutral salt, which readily flows like wax at the fire: whence, some chemists have thought themselves possessed of the great secret of making an incrated fixed alkaline salt, highly extolled by the ancient artists: tho' this is only owing to the volatile acid of the air joining with the alcali, so as to form a compound neutral salt that easily melts at the fire.

11. The fixed alcali, thus procured, has, in a high degree, all the marks before laid down for distinguishing an alkaline salt; in which respect, therefore, it may serve as a standard to these kinds of salts, which, if any doubt arises, may be compared therewith. And hence we may be convinced of what was above said, *viz.* that alcalies, made by burning, consist of three different principles, or of a pure alcali, a bitter salt, and a pure earth: but the truly saline part is here much less than one could have imagined, or so little as to be insensible and volatile. Whence its proper nature cannot hitherto be known, as not being a fit object of our senses.

12. The gross lee which wines deposite after their fermentation is over, *The alcali being pressed dry, and burnt to ashes in the fire, afford a fixed alcali, by the same treatment as above-mentioned of pot-ash; tho' the alcali, thus obtained, is purer and stronger than that, on account perhaps of the subject being more subtilized by fermentation: which shews us another general way of procuring fixed alcali from all sorts of wine.* *from wine lees.*

13. Tartar differs greatly from wine-lees, as concreting into a stony hardness; whereas wine-lees are a loose and softer substance, falling to the bottom of the vessel, whilst tartar strikes to all the sides thereof. Tartar also differs according to the wine that affords it; being red, brown, white, pure, impure, and more or less acid, correspondently to the wine. Acid and rough wines afford it copiously; but sweet and soft wines more sparingly. This tartar being distilled with degrees of fire in a sand-furnace, affords a flatulent spirit, that cannot be confined; then a small proportion of acid spirit, which gradually comes over more gross and unctuous; and lastly, an oil of a more penetrating nature than any other; a black and sharp alkaline coal being now left behind in the retort. And this is the only way that I can recollect, of producing a sharp, fixed, alkaline, vegetable salt, in a close vessel; for all other kinds of vegetable subjects, upon being distilled by the retort, tho' they at length afford a black coal, yet never, that I remember, yield an alkaline salt, till they are burnt in an open fire. So, upon burning this black alkaline coal of tartar, in an open fire, it affords a white alkaline salt, stronger and purer than all others. Whence it appears that fermentation may forward the production of alcali in vegetables; tho', at the same time, vinous fermentation promotes the generation of an acid: so that both acid and alcali have their

their generation forwarded by the business of fermentation; which is an observation of no small consequence.

14. But, from whatever vegetable fixed alcalies are produced, and in whatever manner; yet, when brought to their utmost alkaline perfection by a violent fire, they all appear to be of the same nature; so as scarce to be distinguishable from one another. One small difference has however been observed; viz. that glass, made of the same flint with different fixed alcalies, often appears of different colours: but here we know how small a matter may occasion a great change of colour in glass; as the bare beating of the fixed salt, in a metallic or marble mortar, may alter the colour of the glass. Whence I have sometimes doubted, whether it were not something metallic in the vegetable, and adhering to the fixed salt, that thus gives a different colour to the glass: iron may easily mix with vegetables, and so perhaps may copper.

Fixed nitre.

25. The chemists have discovered another origin of fixed alcali, viz. from nitre; and *Glauber* has justly described it. For if pure nitre be melted in a clean crucible, it presently runs like water, with little or no visible motion; when, if a bit of burning charcoal be thrown into it, this instantly occasions a considerable crackling, and the coal is tossed about upon the surface of the nitre; and when the coal is consumed, the nitre flows quietly again: but fresh bits of lighted charcoal being successively thrown in, till the nitre will deflagrate no longer, what remains is a perfect, fixed, alkaline salt, answering to all the marks above laid down: tho' it still differs a little from the rest, as containing somewhat of the nitre, not yet perfectly changed; yet this does not manifest itself, till strong oil of vitriol is poured upon the salt, which then presently discharges a vapour, smelling like *aqua-fortis*, in the same manner as when oil of vitriol is poured upon nitre. The oil of vitriol also usually acquires a blackness upon uniting with this alcali; which shews that somewhat of the coal remains in it, from the burnt charcoal thrown upon the nitre in this preparation: so that *Glauber* was not mistaken in saying, that this alcali of nitre differs a little from other vegetable alcali: but when he extols its virtues above all others, he seems to applaud his own discoveries too much.

*Alcali from
tartar and
nitre mixed.*

16. The quickest way of making fixed alcali in a large quantity, is by taking equal quantities of tartar and nitre, in fine powder, mixing them together, and throwing this powder, by a little at a time, into an iron-vessel, heated almost to the degree of ignition; for thus an instantaneous deflagration is made; and a copious, white, fixed alkaline salt immediately produced. This salt seems, in all respects, to be a vegetable alcali, tho' still with some differences; for, upon making *tartarum vitriolatum* therewith arises an *aqua fortis* smell, and the matter turns black; which shews, as in the preceding case, that part of the nitre and the coal still remain therein (a).

*From nitre
and regulus
of antimony.*

A fixed and fiery alkaline salt is also soon prepared from nitre, and the regulus of antimony: for if pure regulus of antimony be melted in a clean crucible, and an eighth part of dry pure nitre be put thereto, the nitre, which o-
therewji

(a) See *Hofman, Obs. Phys. Chem.* p. 241.

therwise runs so easily in the fire, will now require a heat capable of melting copper; and thus appears of a yellow colour: and if the matter be now poured into a melting ecne, the nitre appears like a cake of gold on the top; and, being separated from the regulus, is now so strongly alkaline, as to be caustic or fiery, and easily runs into the air: nor is there any way, hitherto known, of communicating so great an acrimony to any salt, as the nitre here acquires by coming in contact with regulus of antimony. It seems probable, that the sulphur of the regulus here intimately mixes with the nitre; for if this fixed salt be thrown hot and dry into pure alcohol, it immediately makes a red tincture, of a violently caustic nature. And I have observed the same sudden change of the nitre, whether the regulus of antimony were made with iron, or, in the common way, with tartar and nitre; and that this change does not happen whilst the gross sulphur adheres to the regulus, but chiefly when the regulus is perfectly pure, and fused with the nitre. The change is more remarkable, as nitre never turns to an alcali with sulphur; but to a bitter salt, or *sal polybrestum*. It may here increase the wonder, if we consider that nitre is a mild, cool salt, capable of remaining long in the fire, without changing its nature; and that it does not grow alkaline with crude antimony, but instantly upon touching the regulus of antimony in fusion. Whence we may learn, what sudden and unexpected effects may arise, from applying bodies to one another, in a certain manner; and how unsafe it is to draw general conclusions in physics. It also deserves to be remarked, how easily the whole body of nitre turns alkaline, in this experiment, without mixing with the antimony, and barely by touching it, or floating upon the surface of the melted regulus; and that, though nitre of itself melts so very easily, yet it here instantly becomes more difficult to fuse than any other salt. And thus much for the origin of fixed alkaline salts; which we have digested and spoke to under their respective classes. We next proceed to consider the physical actions of these salts all along bearing in mind, that they are produced from vegetables by burning; that art and necessity thus produces an immense quantity of them; and yet that none of them are ever to be found on the earth, where they either are lost in their own form, or soon change to another nature.

17. Perfect fixed alcalies will be found to have the following actions in common; and, first, they powerfully attract water, at a great distance, from all the known bodies wherein it is contained. This appears to the eye as fixed alcali, immediately taken from a violent fire, and suffered to stand in a hot air near the furnace, where no water is discoverable, immediately grows moist, and turns to a liquor, which, by distillation in a dry glass, returns the pure water imbibed by the alcali; at the same time other salts that had attracted moisture, being set in the same place would grow dry, or be deprived of their aqueous humidity, whilst dry fixed alcali runs *per deliquium*. Hence these alcalies are truly attractive of water, so as to dissolve it, unite it to themselves, be dissolved by it, strongly retain it, part from it with difficulty, and being once dissolved therein, cannot be rendered perfectly dry again, by the heat of boiling water.

18. To

18. To illustrate this by experiment; put oil of tartar *per deliquium* into a proper vessel, along with a mercurial thermometer; and upon applying 214 degrees of heat, this liquor will not be dried to a salt: but, for this purpose, it requires to be boiled with a heat of more than 600 degrees; so that scarce any known body more difficultly parts with its water than this salt.

19. I put an ounce of pure dry fixed alcali into a clean glass-dish, and setting it in a close cellar, found that the salt soon attracted a moisture from this confin'd air, at rest, and, by degrees, acquired near three ounces of water before it was fully saturated. Whence I infer, that the quantity of water thus attracted by the salt, must at least have possessed the space of six cubic feet in the air: for, supposing the specific gravity of air to that of water, as one to a thousand, and a cubical foot of water to weigh 64 pounds; then all the ponderous parts in a cubical foot of air will be $\frac{1}{128}$ of a pound. Now, allowing half of these ponderous parts to be mere water, it follows, that a cubic foot of air contains about half an ounce of water. If, therefore, this salt can attract so much water from so large a space, we hence discover an extraordinary power in nature. And *Sendivogius* has justly observed, that the more an alkaline salt is calcined, the more water it attracts from the air. But if any one shall say, that the water here came from the remote parts of the air moving nearer, so as to touch the fixed alcali, and give out their water; I can only reply, that I made the experiment whilst the air was at rest in the place.

20. For farther satisfaction, I took a large glass-vessel, as clean and dry as if it had just come out of the nealing-oven; and, first heating it, I put therein a quantity of hot and dry salt of tartar, reduced to fine powder; then stopping the mouth of the glass with a dry cork, tied close down with a soft oiled bladder, I found the salt, sticking to the sides of the glass, grew wet with the water it attracted from the small quantity of air contained in this close vessel; tho' the air itself was dry and hot, at the time when the bottle was corked.

Repels air.

21. Fixed alcali seems to have a contrary property, with respect to air; so that, tho' it attracts water, it appears to repel true elastic elementary air: the contrary whereof might be expected: for, as this salt so powerfully attracts moisture from the air, it might be suspected that it attracted air by itself at the same time; especially since we above shewed, that all water attracts air, after being once deprived thereof; and as all air may be supposed driven out from this salt, by the violence of the fire. And yet, when oil of tartar *per deliquium* is put into the air-pump, it yields no sign of containing air, even tho' the liquor be heated. Whence one might be apt to infer, that fixed alcali not only repels air, but even expels the air contained in the water attracted by the fixed alcali, in making the *oleum tartari per deliquium*; and consequently, that this salt has a power of dislodging and dipelling air from water. But we have already treated this subject in our chapter of air; and rendered it somewhat probable, by experiments, that fixed alcalies strongly attract, and closely unite air to their own substance, so as not to part with it again, but by the utmost force of fire, or the intervention of effervescence.

Or strongly attracts it.

I leave it therefore to be farther examined, whether fixed alkalies totally repel, or strongly attract, and fix air in them; one of which must needs be the case: and, after so many experiments as I have made to this purpose, I cannot help doubting of the alternative.

22. The strongest, purest, and driest fixed alkali, taken hot from the fire, and mixed with pure alcohol, is attracted thereby; but if ever so little water adheres to either of them, the water is immediately attracted, and the alcohol repelled, so that they cannot afterwards be united by any known method; whilst thus the alkali separates the spirit of wine into two parts, viz. a saturated solution of the salt, and pure alcohol floating above it; which two cannot be mixed together. And here also we may see, that the attractive force betwixt the water and the alkali is reciprocal: thus, if a pound of pure alcohol contains a small proportion of water, and fixed alkali be put thereto, the alkali presently attracts the water, and appears like a viscid oil on the sides of the glass; the alcohol, at the same time, being kept from uniting with the alkali. Whence we may understand, that many particular physical operations are performable by fixed alkalies, acting upon liquors prepared by fermentation; the alkalies here acting either by attracting or repelling the alcohol, or by attracting the water alone. These alkalies also act, in another respect, upon liquors procured by fermentation: for, as all spirits distilled from wines constantly have a volatile acid mixed with them, the alkali, by strongly attracting it, renders the spirit purer, deprives it of acidity, and thus greatly alters the nature and virtue of the spirit; at the same time the alkali it self is so changed, as to become a compound salt; or if the saturation be complete, the neutral purging salt of *Sennertus*. And to this observation is owing the method of procuring pure alcohol without fire, and without distillation; for, by mixing a proper proportion of pot-ash with brandy, and stirring them together, the alkali will attract the water, and fall to the bottom; leaving the alcohol at top, so as to be poured off by inclining the vessel. If the alcohol is not sufficiently rectified by this first operation, fresh pot-ash being added to it as before, will render it still purer. It is observable, that the spirit of wine, in this operation, always gives out an unctuous substance; which did not appear before, either in the spirit or alkali, but is produced upon their being thus mixed together.

23. Fixed alkali also has the power of attracting distilled vegetable oils; thus, if dry, strong and pure fixed alkali be taken hot from the fire, and put into a distilled oil, it eagerly, and with a hissing noise, draws the oil to it self, and unites therewith, so as directly to make a kind of soap; which may be rendered more perfect, by setting it in a cellar, where the union becomes more intimate: for thus the mixture becomes uniform, and exhibits a mass which is semi-volatile, dissolvable in water, and of great medicinal virtue; so as to be called the less elixir of the philosophers, *Starkey's* volatile salt of tartar, *Matthews's* great corrector, the soap of *Helmont*, &c. This, as a medicine was first greatly celebrated in *England*; and from thence spread over all *Europe*. It has the virtue of resolving and fusing almost all the tenacious substances produced by a coagulation of the juices in the body; so as to open obstructions, attenuate the fluids, gently stimulate the solids, promote perspiration,

ration, sweat, urine, and thus remove the cause of obstinate chronical diseases. If digested with simples, it changes their nature, and sometimes their particular virtues; so as, in many cases, to correct their virulency, and give them new properties: but, after the usual manner of chemists, its virtue, as an universal medicine, has been too much extolled. As to its preparation, it must be remembered, that the oil and salt can never unite, if ever so little water be lodged in either; and consequently, that fixed salts, used cold, will not here answer the purpose: and even, if a fixed alkali should rise above the surface of the oil, and touch the air, the salt would thus grow wet, and prevent the effect. Fixed alkali easily unites with animal or expressed vegetable oils, by means of quick-lime, water and fire; as we see in making the common soaps. And a pure soap, thus prepared, has a surprizing power in producing many effects, not easily to be otherwise come at; as we saw above.

And acids.

24. Alkaline salts strongly attract all kinds of acids, whether dry or moist, strong or weak; and this more powerfully than they attract water: for, in their attraction of acids, they always violently expel the air contained in either salt, and thus produce numerous air-bubbles; at the same time remarkably repelling water, and thus becoming saturated, they easily grow dry or part with the water; which, when separate, they strongly retained. Thus, rectified oil of vitriol, and *oleum tartari per deliquium*, do not easily let go their water separately; but, upon mixing them together, they expel the water from them, so as to leave an almost dry salt at the bottom of the separated liquor, as we see in preparing the *tartarum vitriolatum*; and the same holds of other acids mixed with alkali: whence many abstruse particulars may be cleared up, in the history of menstruums. But alkalies have a limited power in attracting acids; and there is a great diversity among them in this respect, tho' rather owing to the difference betwixt the acids and the alkalies, as the excellent *Homburg* has usefully shewn (b); from whom we shall here transcribe a few experiments. (1.) An ounce of salt of tartar attracted all the acid from 14 ounces of strong distilled vinegar; and, after drying, was found to have gained 3 drams and 36 grains in weight; the other parts of the vinegar being mere insipid water: whence we see the proportion there was between the acid and the water in this vinegar. (2.) From spirit of salt, it absorbed two ounces, and five drams; and, when dried, became heavier by 3 drams, and 14 grains. (3.) From spirit of nitre, it absorbed 1 ounce, 2 drams, and 36 grains; thus increasing its weight 3 drams and 10 grains. (4.) From *aqua-fortis*, it took up 1 ounce, 2 drams, and 30 grains; increasing its weight by 3 drams and 6 grains. (5.) From oil of vitriol, it gained 5 drams; and was augmented by 3 drams and 5 grains.

25. And as these are the principal among the acids, it hence follows, (1.) That acids, tho' very different from one another in density, yet, after being saturated with an alkali, become of the same density; since vinegar, which is the lightest of these acids, when all its acid is totally absorbed by an ounce of salt of tartar, increases the weight of that salt as much as it would be increased by oil of vitriol, which is the most ponderous acid. And the same holds true of the

(b) *Memoir. de l'Acad. Roy. de Sc. Vol. I. p. 52.*

rest; since the sum of the difference betwixt the greatest and the least acquired weight, is only 31 grains, and this only in the vinegar; on account that the regenerated tartar, so prepared, is hard to dry. (2.) Hence, these acids seem greatly to differ in the proportion of water wherewith they are diluted; since the pure acid, extracted from them, is always of the same weight; so that if, by any method, 14 ounces of strong distilled vinegar could be condensed to 5 drams, and the acid be obtained separate from the water, without farther change, perhaps the vinegar, thus concentrated, would be as strong an acid as the oil of vitriol; at least it might then saturate an equal quantity of alkali. (3.) Hence also we learn, what proportion of water is contained in these acids. (4.) It is also probable, that if acid salts could be obtained pure, without any admixture of water, they would appear in a solid form; and, tho' this has not been hitherto done by art, yet an approach is made thereto by violent cold. (5.) It may here also be considered, what effects alkaline menstrooms must produce in dissolving bodies containing a latent acid, which often consolidates them; and therefore being absorbed, leaves them to resolve into their component parts; whilst, in the action of solution, an effervescence arises, numerous air-bubbles are discharged, and produce elastic air: which sudden effects cannot be understood without the doctrine of alkalies above delivered. When an acid is slowly poured to an alkali, in a warm liquid state, and the containing vessel is shook after each addition, at length the point of saturation will be obtained, and no ebullition appear; and after this, if more of the liquid acid be added, it produces no more commotion than arises upon pouring water to water; whilst the compound salt, thus produced, is neither acid nor alkaline, but neutral, and called by the name of the acid which saturated the alkali. And hence acids have been termed male, and alkalies female salts; and those compounded of the two, hermaphroditical, &c.

26. The strong ebullition and effervescence which happen upon the mixing alkalies with acids, perhaps arises from the violent expulsion of the air and water, whilst the acid and alkali forcibly rush into each other, and strike away what lay between them to obstruct the union of their particles. Whence we may make the following queries. (1.) Whether acids abound with air, whilst alkalies contain none? (2.) Whether acids, predominating in the bodies of animals, are the cause of flatulency? (3.) Whether compound salts, made by a combination of alkali and acid, lose their air, and thence occasion no flatulency in the body. (4.) Whether, therefore, acids, or bodies tending to acidity, are the only fit subjects of fermentation? (5.) Does the struggle and discharge of air, in fermentation, arise from hence? (6.) Does fermentation, from hence, tend to generate an acid, which, by the action of calcination, generates an alkali? (7.) And is this the cause, why fermentation, which generates an acid, requires only a moderate heat; whilst a greater, as in animals, tends rather to an alkaline putrefaction? Thus much is certain, that these salts rest after complete saturation, and then produce no struggle, upon the addition either of an alkali or an acid salt to the saturated mixture. And hence, alkalies and acids are to be reckoned a-

mong the physical causes, productive of motion in nature, at the time they unite; tho' this cause ceases, when the union is completed.

27. In this action of acid and alkaline menstrooms, it is manifest, that both air and water are excluded: for, upon mixing acids and alkalies together in a fluid form, little, solid, saline crystals appear in the liquor, in the very act of union, whilst the aqueous part is expelled; which, after the saturation is completed, may be poured off in the form of water, having no saline taste: and then the neutral salt, upon drying, turns to a white, opake, mealy powder. Such compound salts also dry easily, and with a gentle fire; whereas the simple acids, and alkalies, they were made from, are dried with difficulty.

28. And tho' the neutral salts, thus prepared, easily part with their water; yet the alkaline, and acid salts from which they were made, are difficultly separated, by the bare force of fire, into the pure salts they were before: thus sal-ammoniac, made from the volatile alkaline spirit of that salt, and the spirit of sea-salt, being sublimed, the sal-ammoniac does not separate into its component salts, but they both rise together: and the like holds of *tartarum vitriolatum*, regenerated sea-salt, nitre, tartar, &c. tho' there are other artificial ways of resolving these compound salts, into their constituent acids and alkalies; upon which some secret operations in chemistry depend. And, in order to understand this method of procedure, we must next consider some other properties of alkalies.

Alkalies attract acids variously.

29. Tho' alkalies attract all the known acids, yet they attract some much more strongly than others. Thus, for example, when an alkali is saturated with vinegar, as in regenerated tartar, and the spirit of nitre, spirit of salt, or oil of vitriol be added thereto; the latent alkali here attracts the acid so added, and lets go the vinegar wherewith it was saturated before: so that now the spirit of vinegar may be drawn off from the mixture with a gentle fire, and leave a regenerated nitrous salt at the bottom of the vessel. So again, when alkali is saturated with spirit of nitre, if spirit of sea-salt be added, an *aqua-regia* will rise from it by distillation, and leave a nitrous salt behind, tho' somewhat changed in its nature. Again, if alkali be saturated with spirit of salt, so as to become common salt, and spirit of nitre be added, an *aqua-regia* is thus obtained by distillation, leaving a nitrous salt behind, capable of fulminating with an inflammable matter; tho' it differs in its nature both from nitre and sea-salt. Hence, in these two last cases, as there is no great difference, with regard to acidity, between the spirit of nitre and the spirit of salt, one of these acids some way expels the other; so that they both rise mixed together; whilst a part of them both also remains behind in the alkaline salt.

30. If oil of vitriol be poured to an alkali, saturated with spirit of nitre, the spirit of nitre is immediately separated, and the acid of the vitriol remains united with the alkaline part of the nitre; and, by distillation, leaves a salt behind, resembling *tartarum vitriolatum*, but in some respects differing from it, yet without having the properties of nitre. If oil of vitriol be added to sea-salt, there presently arises a very volatile, fuming, acid spirit of sea-salt, having almost all the known properties of that spirit; being only more volatile,

tile, more smoaking, and more suffocating, till rectified. Hence it appears, that those acids, which are naturally diluted with a small proportion of water, have a greater power of uniting with alkalies, than those that are diluted with a larger. The following rules seem therefore to be general; *viz.* (1.) That the stronger acids constantly separate the weaker, from the alkalies they lodge in. (2.) That these stronger acids then unite to the alkali, in the place of the weaker expelled. (3.) The salt, thus generated, now becomes of the nature of the acid last united with the alkali. (4.) There is always a considerable difference between the salts thus produced, and the natural salts which afforded the acids. So, for example, the *sal mirabile Glauberi*, made by the distillation of sea-salt with rectified oil of vitriol, is of a very different nature from that made by mixing oil of vitriol and oil of tartar together: and the like holds in other instances. So again, the salt prepared in the distillation of *Glauber's* spirit of nitre, is of a different nature from that of the *sal mirabile Glauberi*; tho' both are here supposed to be made of the same acid and alkali. And hence we may correct that general rule of the chemists, which says, that acids always convert alkalies into the nature of the acid, so as to produce the same salt as the acid did before.

31. We may here farther observe, that when these acids are added to compound salts, they dislodge the former acid, and unite to the alkali, without any conflict or effervescence; whereas a considerable tumult is rais'd upon the first joining of an acid to an alkali: nor does any air appear to be here generating upon this uniting, tho' at first a large quantity was discharged. This seems owing to the preceding saturation having expelled all the air in the effervescence then made; so that the second acid enters the saturated alkali, already deprived of its air, and remains therein, without any more being expelled or attracted: for if the acid, here displaced by a stronger acid, be mixed with a fresh quantity of alkali, it again produces as strong an effervescence as at first, generating air, and raising a conflict, scarce any signs whereof appeared in the compound salt.

32. And hence we may understand the wonderful transmigrations and regenerations of acid salts, from whence numerous physical arts may be discovered, and improved; as also many surprizing, and hitherto unknown, changes of bodies; whilst neither the examples nor instruments thereof have been met with: so that no explanation can be given of them, upon any other principles hitherto known. It was necessary to mention these things in the history of alkalies, considered as menstrooms, otherwise numerous phenomena wou'd every where occur, in the application of these alkalies, whilst they could not be understood without a knowledge of these observations. Here also occur several particulars, deserving to be farther enquired into; as,

(1.) Whether all fixed alkalies are generated by fire alone? (2.) Whether all volatile alkalies are produced by a putrefactive heat? (3.) Can any fixed or volatile alkali long retain their nature in the open air? (4.) Whether their nature will not be altered, or the salts changed, so as to become neutral or saponaceous, by thus meeting with acid or oily particles? (5.) And will not the same happen in the bodies of plants and animals? (6.) Is not a large quantity of compound salts thus daily produced; especially of such salts

whose

whose component acid is very where common, and ready at hand? (7.) And, as natural acids, or those produced by fermenting vegetables, abound every where, is there not, in nature, a very common salt, of the same kind with regenerated tartar, or the spirit of *Mindererus*, made with a volatile alkaline salt and distilled vinegar; being a mild, penetrating moveable salt, of no great taste? But there is nothing of this kind more deserving to be known, than the origin and nature of the most common useful salts; viz. sea-salt, spring-salt, sal-gem, and nitre: which, whether they are made by a combination of their own acids, such as we find by chemical distillations, and a fixed vegetable alkali, deserves to be enquired; or whether, being produced simple by nature, they are not rather changed, than separated by fire. Many eminent chemists, since the doctrine of acid and alkali prevailed (c), maintain, that all these salts arise, and are naturally produced from the mixture of acids with alkalies. But it is highly probable, that salt was contained in the sea, before the acid spirit of salt was present therein; and before any fixed alkali was made from vegetables. On the other hand, no known experiment hath hitherto produced the least fixed alkali from sea-salt. Thus much is certain, if pure and dry sea-salt be intimately mixed with thrice its weight of common dry bole, and carefully distilled with all the degrees of fire, it constantly yields a certain proportion of acid spirit; beyond which no more can be obtained from it, with the utmost violence of fire; whilst the bole will still remain saline in the retort; and being well washed from all its salt with water, if the solution be well purified and evaporated, some sea-salt, but no fixed alkali, will be obtained. Nor do I learn, that the acid spirit of nitre, or of sea-salt, was ever hitherto found naturally, but always as produced by art or by fire; and this rather by a change, than a separation of parts. It is true, these acids, properly mixed with alkalies, regenerate, in some sort, the salts which afforded the acids; tho' always with some difference between the native and artificial: which shews, we cannot be so certain as to the composition and resolution of these salts, as some authors pretend. We may hence learn, what caution is required in using alkalies as solvents; since a change, in any circumstance, or a slight addition of a foreign substance, may easily change an alkali, and produce a salt that shall not operate as a pure alkali, but according to the nature which is thus introduced.

Glass from
fixed alkali.

33. It remains to be considered of pure fixed alkalies, that sometimes, when they are applied as solvents to certain bodies, they not only seem to procure a perfect solution, but presently after unite with them into a mass that can scarce be dissolved again by any menstruum; the mass thus appearing extremely remote from the alkali here employed. For example, if to a hundred weight of clean sand, or flint reduced to a calx, and ground to fine powder, a hundred and fifteen pounds of pure fixed alkali be added, and thoroughly mixed therewith, and the mixture be set in a glass-house furnace, with a moderate fire, for an hour, and kept stirring all the while, the fire being afterwards increased for five hours; whilst the stirring is all along continued; a mass will thus be obtained, rightly disposed for making the finest glass. If this mass be put into dry casks, and kept in a warm,

(c) See *Fran. Travaglin. & Ott. Tachen. de acido & alkali.*

dry place, for four or five months, the ingredients will thus be more intimately united: and if now, the matter be put into glass-house pots, set in the hottest part of the furnace, it will thus melt into a kind of viscous, thick, and apparently unctuous fluid, casting up a froth to the surface as it boils; which froth rising more and more, often amounts to a fourth part of the whole mass. This frothy matter being carefully skimmed off as it rises, till no more appears, and the remaining purified matter being kept in constant fusion for two or three days, the matter thus remaining behind in the pot, is what the glass-men call their metal; and when cold, makes the best sort of glass. Now, unless this was proved to us, by very day's experience, who would have suspected, that fixed alkali, which runs into a liquor in a dry air, should thus with sand, melt into a matter so like a metal, except in malleability? This property of alkali, was not to be omitted in the history of alkaline menstrooms. Here, therefore, we see when the alkali is brought by the fire to run like water, it becomes so powerful as to fuse sand, or flint, into an almost aqueous form; being itself, at the same time so changed, as to appear with a set of new properties, and retain nothing of its former nature.

34. This affords us an instance how such menstrooms as have a strong dissolving power, may permanently concrete with the bodies they perfectly dissolve; the concretion being the stronger, as the solution was more perfect. And hence we learn that alkalies, sometimes, when they dissolve perfectly, may be so changed in the action, as totally to lose their own saline nature: for, if there be any body far removed from the nature of a salt, glass will doubtless be allowed for one; yet, glass contains nearly a third part of alkali in its substance. It may also seem extraordinary, that fixed alkali should here so suddenly lose its alkaline nature, in the action of dissolving and passing into glass, so as not to retain any one mark of its being an alkali; for it here becomes tasteless, makes no effervescence with acids, changes no colour in bodies, has not the least acrimony, and becomes more fixed in the fire, and harder to melt, than it was before. It is also extraordinary, that the glass thus made, melts into a tenacious, tough, ductile mass, so as to be formed into vessels of any figure; and sticking so strongly to iron, as to be thereby taken out of the melting-pot. Another remarkable particular is, that two opaque bodies should thus concrete into a pellucid solid, not to be dissolved by any known menstruum; tho' itself, in part consists of the most soluble of all salts: for glass is neither dissolved by water, spirits, oils, acids, alkalies, simple or compound salts; nor, even by the philosophic spirit of wine, nor the circulated salts of the adepts, nor even by the philosophical mercury: all these higher menstrooms being, as authors constantly relate, prepared in glass-vessels, many whereof are constantly used in the digestions, distillations, circulations, fixations, and solutions; and even in the operations of the alkahest itself.

35. Hence we see how difficult it is, to assign the origin of any physical body, or to ascertain the principles whereof it is composed; and to separate the body into its principles: so as, thence to discover a way of compounding the like. Thus, supposing an artist ever so well versed in natural philosophy,

but

but to know nothing of the art of glafs; what judgment could he form of glafs, when he saw it? Could he ever suspect it was made of fixed alkali and flint united together in a strong fire? It is therefore bold, in philosophers, little conversant in experiments, to assign the origin, nature, and principles of gems: it were better to confess our ignorance, than to cherish great expectations upon slender acquirements. To judge rightly of these matters, we should, not only know the nature of the principles concerned, but also the power of fire, whereby the principles may be changed in the act of union!

Alkalies differ in purity,

36. Having thus considered the origin, nature, and effects of alkaline menstrua upon some principal bodies; we must next observe, according to what was above laid down, that as the vegetables, which afford fixed alkali by burning, contain an acid, more or less cleaving to it, whence the alkaline salt will become of another nature than if the acid were not present therein: understand the same of oil and earth adhering to the salt: on which account, there will be a great difference betwixt fixed alkalies, as they contain more or less of these principles: whence, it is no wonder that certain experiments with alkali, as related by some authors, do not succeed, when tried with different alkalies.

And from additions.

37. Alkalies also may receive great alterations from other things added thereto: thus in particular, their power is greatly increased, and an almost fiery, consuming virtue given to them, by being mixed with quick-lime, prepared from shells, stony sea-plants, or lime-stone: for, by this means a salt may be obtained so strong and corrosive, as to dissolve and fuse almost all the solids of animals and vegetables by boiling. Whence, we see a strong alkaline solvent may be prepared from the same ingredients, which make unactive glafs. Again, fixed alkali, rendered stronger by quick lime, and afterwards dried at the fire, easily melts like wax; and thus, by an extraordinary virtue lays hold of and dissolves bodies put into it. And this, perhaps, may be the secret artifice, which some of the ancient chemists are said to have, of performing extraordinary things by an alkali of easy fusion; and perhaps is their incrated salt of tartar, so called from its readily melting like wax.

The limitation of the power of alkali.

38. There are, however, some bodies upon which fixed alkali has no effect as a menstruum; thus it does not dissolve, nor any way affect pure quick-silver, in what manner soever applied thereto: and hence also, it exerts no dissolving power upon those metals, which, according to the adepts, consist of a pure mercury, and a fiery metallic, fixing, sulphureous spirit. Thus, gold and silver are not changed by it, that I know of; tho' it has some action upon the other metals; perhaps because to their mercurial parts they have added another, which approaches to the nature of an unctuous and sulphureous substance. But, as these external sulphurs are not easily separable from the metallic matter with which they concrete; hence it often happens, that when these alkaline salts act upon such sulphurs, they may seem to change the mercurial part of the metals, intimately united with the sulphur, without being able to touch the mercury in its own pure nature; as I have plainly experienced, by melting common antimony with salt of tartar,

tartar, nearly the whole body of the antimony, or both its sulphureous and mercurial part, was dissolved into one brown mass, without affording a regulus: but, when the regulus of antimony, now separated from its external sulphur, is melted with fixed alkali, the alkali flowing thin on the top of the metal, extracts from it something sulphureous, and becomes of a gold colour; whilst the regulus itself, remaining at the bottom, is thus made purer and whiter. Here, therefore, the dissolving power of alkalies, with respect to metals, seems to be limited; for, when applied to calcined metals, and assisted by the force of fire, they seem not capable of dissolving that sulphur which fixes their mercury, and gives them the metallic form: no method of applying fixed alkalies having hitherto, that I know of, obtained the mercuries of metals. And some of the greatest proficients in this art, after all their experiments, have given it as their opinion, that these mercuries have been rather seen by the eye of reason, than the eye of experience. As for myself, after all the labour I have bestowed upon the subject, I could never meet with the success promised in books; so that, if what Mr. Boyle, Tachenius, and M. Homberg, relate of recovering the mercury of metals be true, some secret process is required to make these regenerating alkalies enter the fixing sulphur of metals.

39. Both the fixed and volatile alkalies have a dissolving power, (1.) *Its action upon bodies.* upon animal, vegetable, and mineral substances; so far as these contain oils, balsams, gums, rosins, or gummy rosins, or consist of unctuous matters; as also upon sulphurs, whether pure, compounded, or joined with other materials: all which, these alkalies excellently open, attenuate, resolve, and dispose to mix intimately with water, alcohol, and oils. Thus, alkalies have a great effect in extracting of tinctures, which afford excellent remedies. Gum-hedera, gum-juniper, gum-lac, myrrh, &c. which otherwise scarce dissolve in water, or alcohol; readily dissolve therein, after being prepared for the purpose with these alkalies, or diluted, heated, and dried therewith, over a gentle fire. (2.) These alkalies, also, act as a solvent, upon such bodies whose component parts are held together by an acid cement; which being thus attracted by the alkali, the component parts now separate or fall asunder: but, here, the acid is often so intimately united with the subject, as not readily or entirely to be extracted at once, tho' in time it usually is. Thus, quicksilver being dissolved by spirit of nitre, and turned into red precipitate, by the action of the fire, does not presently return to running mercury, upon the affusion of oil of tartar *per deliquium*, but changes to a different powder; which being distilled in a retort, with a strong fire, the mercury, leaving its acid in the fixed alkali, comes over in its native form. (3.) After certain bodies have been once dissolved by an acid menstruum, pure alkalies often exert a new power, so as to dissolve such bodies better than if applied to them before they were thus dissolved by the acid: whence it is, that alchemists direct, in order to obtain the mercuries of metals, that the metals be first calcined by acids, and afterwards be treated with alkalies.

40. We must here bestow a short consideration upon volatile alkali, as *Volatile alkali.* a menstruum. Whether any volatile alkali exists in nature, without the

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assistance

assistance of putrefaction, or the distillation, of animal or vegetable substances, is not easy to determine; unless we should say, that the particular salt found in mineral waters, is of this kind; tho' such salt cannot be, justly, reduced to the class of volatile alkalies: however, Dr. *Hoffman* has shewn, that they rather belong thereto, than to the acid tribe. On the other hand, all animal and vegetable substances are, by putrefaction, brought to afford a perfect volatile alkaline salt: the acrimonious pungent vegetables, and all animal substances afford it upon bare distillation; and such animal juices as are not alkaline, yet upon being mixed with fixed alkali, are so changed, as immediately to yield alkaline exhalations, and by the action of the fire, afford a volatile alkali, the other parts being attracted into the fixed alkali. These salts, however produced, may by chemical treatment be rendered pure, of the same virtues, and of the same form; their virtues being similar to those of fixed alkalies, tho' with some difference. Thus volatile alkalies act, and are agitated spontaneously, or by a very small degree of heat; whereas, fixed alkalies, require a much greater assistance from fire, in order to their acting: volatile alkalies fly off the instant they are heated; and, therefore, do not exert their dissolving power when applied to heated bodies; whilst fixed alkalies sooner enter the bodies they dissolve, when assisted by heat; and remain constantly applied to every fixed subject they act upon. But, when volatile alkalies are purposely kept close to a substance to be dissolved, a moderate heat then increases, and quickens their dissolving power; as we see upon applying the volatile salt of urine, for instance, to the warm skin, and covering the salt with a sticking plaister; for thus, there soon arises heat, pain and inflammation upon the skin, followed by an ulcer, and a black eschar: and, allowing for these differences, the action of volatile alkalies may be understood, from the history above given of fixed alkali.

S E C T. VIII.

Of acid MENSTRUUMS.

Native, vegetable acids.

I. **W**E have already delivered the physical marks of an acid, and observed that acids are seldom found in a solid form; except in the essential salts of acid or austere vegetables, or in tartar. All acids arise either from vegetables or fossils; none, that I know of, being found peculiar to animals. The vegetable acids are either native, or produced by fermentation. The native vegetable acids seem to arise from that juice which plants attract out of the earth, in the way of nourishment: whence, in this respect they may, perhaps, all be reduced to the fossil tribe; especially, since the sea-plants, which have no root growing at the bottom of the sea, consist of mere alkalescent parts; and by distillation afford a volatile unctuous alkali, according to the observations of Count *Marssigli* upon this subject. The native vegetable acids are very manifest in some plants, as in sorrel, &c. and, again, in the juices of unripe fruits, which grow milder as they ripen; and, in all the juices of plants, upon the return of the

the spring. In some vegetables there is a more latent acid; particularly in woods, and spices, as guaiacum, cinnamon, &c. where one could not have suspected an acid, if it did not clearly appear upon distillation. Nor, would any one suspect an acid in balsams; yet turpentine by distillation affords it copiously. But all these acids can scarce be obtained pure; being generally mixed with other materials; so that their actions can scarce be distinctly enumerated: yet their power appears by their operation upon suitable subjects; as, when the juice of oranges, or of lemons dissolves and corrodes iron, copper, lead, and tin, after the manner of mineral acids. These fluid, acid vegetable juices, are also, by another treatment, reduced to solid saline crystals; viz. by being purified, inspissated, and set to shoot; as we remarkably see in the juice of sorrel, which thus affords a salt like tartar, and contains the true native acid of the plant.

2. Fermentation, also, seems to disclose or increase the acid latent in vegetables: thus, tho' the sweet, ripe vegetable juices seem to contain little, or no acid; for example, the juice of ripe grapes, honey, sugar, &c. yet after they are properly fermented, an acid is directly extricated from them; as remarkably appears in the wine made from them. So again, there is no sign of acidity in malt, wheat, &c. yet, by fermentation they soon grow acid. It is true, the acid thus produced, is more subtile than the native: whence, we may term it a vinous acid; which also is of two kinds, viz. as it floats liquid in the wine, or shoots from it in the solid form of tartar to the sides of the casks. And these fermented vinous acids have nearly the same properties with the native.

*Fermented
vinous acids,
both liquid
and solid.*

3. The other vegetable acids, produced by fermentation, I choose to call acetous: for all the known wines, properly treated by a second fermentation, turn sour, consume their own tartar, and thus become vinegar, which is a strong acid; and afford a large quantity of acid spirit by distillation. The use of this vinegar is so great, and general, that, in a manner, all other menstruums have hence been called vinegars, and extraordinary solvents the vinegars of the philosophers.

Acetous acids.

4. To these acids we may add, as another kind, those vegetable juices which, being only half fermented, are in a middle state, betwixt the native and fermented acids; and give them the name of the fermenting kind: which in this state, have such a property, in their elastic fermenting part, as is not to be otherwise found in nature, as I know of. For, the gas, or highly expansive and explosive acid spirit, here produced in great quantity, being received into the nostrils, from a small hold made in the cask, will instantly strike a man dead; or at least, occasion a sudden apoplexy, palsy, stupor, or vertigo; as has been found by sad experience. Whence we may have a notion of the more immediate cause of drunkenness, and disorders of the nerves, from thence arising. And hence we may account for an extraordinary phenomenon related by Cornaro, of himself, in his excellent treatise of sobriety; viz. that in his old age, he was every year seized with a languor and faintness, near the time of vintage; for which he could find no remedy; so that, at length, the disorder increased to an extreme degree: but, immediately upon drinking new wine, he recovered his strength,

*Fermenting
acids.*

and soon after, his former vigour; but as the year declined, and the wine of that year grew older, he relapsed and continued ill, till he was again recruited by drinking new wine in the autumn. Hence, therefore, we see what an incredible effect the fermenting acid may have upon animals, both to their relief and prejudice. And on this account it seems to be, that the *cholera morbus* is often so suddenly fatal; viz. either from new wine or summer-fruits, fermenting in the stomach, and intestines, and discharging their gas into the muscular coats of these parts, so as to occasion a terrible spasm: to which purpose there is an extraordinary account, in the philosophical transactions, where that excellent anatomist, M. St. Andre, accurately describes the case of a man, who was opened after dying of this distemper, from drinking too freely of new bottled-ale. And as we, hence, see such an acid may have a singular effect; probably it may also act as an extraordinary menstruum in other respects. I have sometimes suspected, that this surprising spirit is fixed in tartar; and coming to be set loose in the distillation of that substance, occasions so violent an explosion, as to burst the glasses; which is a common accident in the distillation of tartar; as chemists well know. It is certain that bodies suffered to remain in fermenting liquors, are acted upon very differently from what they would be, if put into the same liquors after fermentation; as we see, when recent plants are put into fermenting wort; whereby a liquor is obtained, thro' which the virtues of the ingredients are equably distributed, so as to act like an entire substance; or as Venice-treacle, mithridate, &c. tho' composed of numerous different ingredients, brought into an uniform mass with honey, act by the joint virtue of the whole.

Vegetable
acids by burn-
ing.

5. Pure active, attenuated, and almost native acids, are also obtained from vegetables committed to the fire. Thus, if green wood be laid upon a clear fire, so that its ends may reach beyond the grate; the fire then acting upon the middle part of the wood, fuses the juices therein contained, and drives them out at the extremities, with a hissing noise and froth, in the form of water: this liquor being collected, is a pure acid, having all the properties, and the dissolving virtues common to acids. Whence, we see why the smoke of wood is so pungent to the eyes; viz. on account of its discharging every way, into the air, so sharp an acid, as to enter the substance of flesh or fish exposed to this smoke; tinge them red, and preserve them from putrefying, or growing rancid: the acids, thus procured, being like those naturally found in many kinds of trees.

Distilled
acids.

6. Again, we find several particular acids, of a balsamic and oily kind, produced by distilling vegetables in close vessels, both *per ascensum* and *descensum*. Thus, the dry chips of guaiacum, juniper, oak, &c. afford a reddish, somewhat oily, and strongly acid liquor, of the red-herring smell. The liquor thus procured, may be made stronger by depuration and rectification, so as to become a very particular acid menstruum. It has also extraordinary effects in the human body; where it attenuates, preserves, stimulates, resists putrefaction, and proves diuretic and sudorific: and, if this acid spirit be well purified, it admirably extracts the medicinal virtue of plants; for, by its singular, subtle, penetrating acid, it heightens the virtue of

of what it extracts and dissolves. And all these vegetable acids will intimately dissolve many animal, vegetable, mineral and metallic bodies: they dissolve horn, bone, and the flesh of animals, by being digested and boiled therewith; they dissolve shells into a transparent liquor; and act upon all the metals, except gold, silver, and quicksilver.

7. Chemistry has discovered other acids in aid of the former, and capable of dissolving mercury, silver, gold, and other fossils, which the vegetable acids will not touch. The acids here meant are of the fossil kind, and cannot easily be digested or subdued by the bodies of animals: whereas the vegetable acids may, by the powers of the body, be so changed, as to lose their acid nature, and become another kind of salt; but the known acids, capable of dissolving gold, silver and mercury, are so strong, as generally to destroy, or prove almost poisonous to animals; except in some few cases, where putrefaction, or an alkaline disposition runs high: as when alkaline poisons are swallowed, or the juices acquire a corrosive, alkaline quality; or, again, when the plague, or the pestilential small-pox rages.

8. The native fossil acids are extremely few, and hard to find: for the mineral waters called *acidulae*, are so far from being acid, as rather to give all the marks of an alkaline nature. But there is often found in mines, a damp or vapour, smelling like a sulphureous suffocating acid, and giving other marks of its acidity; tho' this is seldom found alone, or in a pure liquid form; but, meeting, as it often happens, with a solid body, capable of attracting this acid, it unites thereto, and thus becomes fixed and palpable: and, when extracted again from this fixed body, it is manifest to the senses; and so far as we can distinguish, is, when rendered pure, constantly one and the same thing.

9. When this general fossil acid meets with unctuous substances in the earth, it thus makes different sorts of sulphur; which by burning in a moist air, afford the *oleum sulphuris per campanam*: a liquor, that being distilled in a glass vessel in *balneo Mariae*, affords a considerable proportion of pure water supplied from the air, and uniting with the acid fume arising from the sulphur in burning. After no more water will come over, there remains at the bottom of the glass, a ponderous, thick, caustic acid, in all respects, perfectly resembling pure oil of vitriol; excepting only, that it contains no metallic volatile part, which always, more or less, remains in oil of vitriol.

10. When this same universal acid enters lime-stone, it concretes therewith, and constitutes alum of a different kind, according as different matters are mixed with the stone; tho' all the kinds, being first gently calcined, and then distilled with a violent fire, afford a vapour which condenses to a liquor, that, when perfectly rectified, is the same, without any considerable difference, as the former, obtained from sulphur burnt under the bell.

11. So again, if native green vitriol be calcined, with a gentle heat, to a white powder, and distilled with degrees of fire up to the highest, it affords a white fume, which condenses to an acid liquor, that when perfectly rectified, is the same with those obtained from sulphur and alum. And, blue vitriol, treated in the same manner, also affords an acid liquor, which when perfectly

perfectly rectified, is not to be distinguished from the former: and, if the acid liquors thus produced, be boiled with the heat of five hundred and sixty degrees, they rise and disperse into white cloudy fumes, which spread wide in the air, and thus presently kill all the known animals and insects. And, if taken into the lungs of men, they soon raise a violent coughing that cannot be stopped, thus bringing on a difficulty of breathing, suffocation, and sudden death; or, else, an incurable asthma for life. The oils of sulphur, alum, and both the vitriols, produced the same effect, when boiled or rarified into vapour by heat: and any of these acids, being united to a fat oil, make sulphur; to a calcarious earth, alum; to iron, copperas; and to copper, the blue vitriol. For these reasons, therefore, we judge, that one and the same ponderous acid, constantly exists native and pure among the fossils.

Properties of
the fossil acid.

12. The properties of this fossil acid are the following: viz. (1.) It is, in its own nature, the most ponderous of all acids; being as 11, when spirits of nitre and *aqua-fortis* are 9; spirit of salt 8; and distilled vinegar about 7 (a). (2.) It is the most fixed of all acids, so as to afford none of its own acid fume with the heat of boiling water, and to require a heat of above 560 degrees to make it boil perfectly; upon which it immediately sends out noxious acid fumes. (3.) This acid, being rectified or purified from all its water, becomes highly corrosive, strong and ponderous, and so attractive of water, as to imbibe it from the air, and thus increase its own weight. (4.) When well rectified, it instantly conceives a great degree of heat upon mixing with cold water. (5.) It produces such a change upon sea-salt, sal-gem and nitre, as, by means of distillation, to make them rise in the form of the spirit of salt, or spirit of nitre; and, when poured upon many other bodies dissolved by acid spirits, it immediately releases them from their acid solvents, strikes them out, renders them volatile, and often substitutes it self in their stead. And hence, if alum or vitriol be calcined and mixed with nitre, they afford an *aqua-fortis*; or, with sea-salt, a spirit of sea salt: for the stronger fixed acid of vitriol lies concealed in these substances, after calcination, and could not be thrown off by the calcining heat: and this strong acid coming to mix with the nitre, occasions a pure spirit of nitre, or *aqua-fortis* to rise, in which there is no oil of vitriol contained; whilst the acid, left behind in the calcined vitriol, remains at the bottom, along with part of the nitre, and thus makes a fixed salt like *tartarum vitriolatum*. And the same is to be understood of sea-salt. (6.) It readily dissolves iron, copper with more difficulty, silver scarce at all, but quicksilver with 560 degrees of heat: it neither dissolves lead nor tin. (7.) In other respects, this acid has the same properties with other acids; and has this in common with some of them, that it perfectly dissolves camphire into a fluid oil; which by pouring a large proportion of water to it, becomes true camphire again.

The acid of
nitre.

13. Another fossil acid is obtained from nitre, and has never been found native, even in the smallest degree; but is always produced from nitre: which being mixed with thrice its weight of bole, brick-dust, or the like, and distilled with a strong fire; a large part of it is thus raised in a red fume,

(a) See *Memoir. de l'Acad. Roy. de Scien. Ann.* 1699. p. 47.

fume, which condensing to a liquor, is called by the name of spirit of nitre. Or, if dry nitre be distilled with an equal quantity of oil of vitriol; in a sand-heat, with all the degrees of fire, a like spirit of nitre, thus also, comes over in red fumes. Again, if this same nitre be ground with an equal quantity of colcothar of vitriol, or burnt alum, and then distilled in a strong fire, it affords the same red fumes, which condense into a good spirit of nitre, called *aqua fortis* by the refiners. And, however this spirit is prepared, it will be found the same in all respects; scarce any experiment being able to shew the difference. This spirit of nitre has these peculiar properties, that it rises in red fumes; and dissolves silver into extremely bitter, caustic crystals: this solution, being in a manner peculiar to spirit of nitre, and scarce to be made by any other acid, for pure oil of vitriol performs it with difficulty. It also dissolves mercury, lead, and copper; but scarce dissolves tin, and will not touch gold. When this acid is intimately mixed with the metals it dissolves, it strongly adheres thereto, so as not to quit them in a considerable fire: as we see, when silver is so dissolved, which thus makes *lapis infernalis*; a substance capable of being fused in the fire, without quitting the acid menstruum. So, likewise, the red precipate of mercury, when properly made, long resists an intense fire, without letting go the acid solvent.

14. When sea-salt is perfectly pure, it affords no sign of its containing *The acid of* an acid; and the same holds also of nitre; like which, by the treatment *sea-salt*. mentioned above, it is changed into a fluid, volatile acid: for, if mixed with thrice its weight of earth, to hinder it from melting; and distilled by degrees of fire, it rises in white, thick, volatile, diffusive clouds; which condense to a liquor of a green, or gold colour; and, if distilled with oil of vitriol, this liquor is more volatile; but in other respects, the same. And whatever method it be obtained by, there is no considerable difference to be found in it; even, tho' sal-gem, or spring-salt, be used for the purpose. The spirit so prepared from pure salt, constantly rises in white fumes; and is a solvent for gold, which no other acid in nature will penetrate. It also dissolves tin (*b*), mercury, iron, and copper; but not silver, nor lead totally: whence we see it is a peculiar kind of acid.

15. Hence it appears, that pure spirit of nitre, and pure spirit of salt, are *Aqua regia*. two very different liquors; which, however nearly approach to each other, and may easily be changed, the one into the other: a particular, well deserving to be regarded in the history of menstrooms. Thus, if spirit of nitre be drawn off from perfectly purified nitre, in a glass-retort; the spirit of nitre is meliorated thereby, and after every such operation, becomes fitter for all the purposes of spirit of nitre: but, if the nitre here employed, be not perfectly freed from all sea-salt, the spirit of nitre so treated, loses its nature, will not dissolve silver, but becomes a kind of spirit of sea-salt, or *aqua regia*, and dissolves gold. And by carefully considering this fact, it will appear to be owing to some nitre remaining in the sea-salt, and mixing with the spirit upon distillation; whence, a true *aqua regia* is thus formed: as may farther appear by the following experiment. Take one part of pure, dry,

(b) Boyle, *Scept. Chem.* p. 177.

dry, decrepitated sea-salt reduced to fine powder, put it into a clean retort, and add thereto four parts of spirit of nitre, or good *aqua-fortis*, distil to perfect dryness in a sand-heat, and you will find the acid spirit, in the receiver, will be an *aqua-regia*, and not an *aqua-fortis*; as dissolving gold, but not touching silver. And upon examining the salt that remains at the bottom of the retort, we shall find it, after solution, purification and crystallization, to be a true and perfect nitre (c). Again, take one part of perfectly purified nitre, and two parts of the best spirit of salt, distil them in the same manner, and a spirit will come over, that dissolves gold much quicker and easier than the spirit of sea-salt usually does; and if the dry salt, remaining at the bottom of the retort, be dissolved in water, filtered and crystallized, it here also becomes true and perfect nitre (d). Whence we see, that *aqua-fortis* becomes an *aqua-regia*, upon the mixing of spirit of nitre and spirit of sea-salt together, in any manner, and almost any proportion. And even if *aqua-fortis* be mixed with a little sal-ammoniac, sal-gem, sea-salt, spirit of salt, or other salts containing these, it presently becomes an *aqua-regia*.

*Conclusions
drawn from
the history of
acids.*

16. From this history of acids we observe, (1.) That acids may easily be produced from substances that are not acid; as we saw above in the production of vegetable acids. And thus some excellent wine, that was not acid, being well bottled, and fixed to the sail of a wind-mill in motion, turned to vinegar in three days time, according to the observation of M. *Homburg* (e). (2.) That, however, acid once produced, and long exposed to the fire, are scarce afterwards changed. Thus *aqua-fortis*, *aqua-regia*, spirit of nitre, spirit of salt, and oil of vitriol, being hermetically sealed up in glasses, and digested for four years, with the uniform heat of an athanor, retained the same dissolving power; whilst only vinegar became insipid, and acquired a spicy odour: but the spirit of salt had, in this time, begun to dissolve its containing glass. (3.) These acids lose their acidity, in acting as menstrua upon the bodies they dissolve; as M. *Homburg* infers, from a curious experiment made upon quicksilver and spirit of nitre (f). Whence it appears, that the strongest acid menstruum, by dissolving its proper subject, is changed into an insipid, unactive matter, no longer retaining the peculiar dissolving power it had before; but thus becoming water, phlegm, or some aqueous liquor: whence, the solvent is truly changed, and the power of dissolving lost in the act of solution. Hence, it is not improbable, that these acids are generated and destroyed; for no spirit of nitre hath ever been found native, but is always produced from nitre already formed. Now this nitre is generated in earth abounding with the excrementitious parts of animals, lime, alkali, and air; or from spirit of nitre, attracted by pure fixed alkali; or lastly, from fertile, rich earth, defended against rain, and not wasted in the production of vegetables (g). Whence, it appears that the acid spirit of nitre arises only from pure nitre changed by the fire; and that native nitre is produced

(c) See du Hamel, *Hist. Acad. Reg. Sc.* p. 158. Boyle, *Orig. Form.* p. 215.

(d) See Boyle, *ubi supra*, p. 215—224. *Bohn. Chem.* p. 35, 36, 163. *Hoffm. Obs.* Chem. L. III. *Obs.* 20.

(e) *Hist. de l'Acad. Roy. de Sc.* Vol. II. p. 11.

(f) *Ibid.* p. 442, 443.

(g) *Mem. de l'Acad. Roy. de Scien.* Vol. I. p. 52.

duced, without requiring a previous production of this spirit. (4.) Therefore, these acids, in dissolving bodies, concrete therewith; and are changed or converted into new substances: and thus numerous, different bodies arise from one; for spirit of nitre dissolves silver, lead, copper, mercury, antimony, zink, emery, &c. and with each of them constantly generates new substances, in all their sensible properties and effects, as Mr. Boyle has shewn, in treating of the mechanical origin of qualities. (5.) All these acids agree in some respects, but differ in others.

17. Acids agree, (1.) In uniting with alcalies, making effervescences there-
with, and producing new kinds of salts. (2.) They also agree in combin-
ing with chalk, coral, crabs-eyes, pearl, mother-of-pearl, shells, horn, bone, quick-lime, iron, copper, &c. all which are dissolved quicker or slower by every acid; the bodies so dissolved, constantly attracting the acid of the solvent, from the water in which it was diluted; the dissolved matter being thus united to the acid salt, and rendered of a saline nature, so as to join with water; whilst the acid adheres to the matter, which would not otherwise dissolve in water. But, when the acid solvent is separated from the dissolved matter; this always appears in the form of earth, and will not dissolve in water. Hence, therefore, we may easily be imposed upon in the judgment we form of water, and take that for pure element which has been employed in certain operations, and holds numerous dissolved and dissolving particles: and hence bodies are often supposed to be produced from simple water, whilst, in reality, their origin is owing to some dissolving or dissolvable particles it contains. And this may happen the more easily, as acids in general, when united to, and saturated with all the bodies above-mentioned, except metals, lose all their acrimony, and almost all their taste, so as to pass without being discovered. Thus, for instance, if spirit of nitre be perfectly saturated with crabs-eyes; this solution will prove a limpid, and almost insipid liquor; and when diluted with fair water, filtered and kept for some time in a gentle heat, it might pass for water it self; but, upon adding fixed alcali thereto, the crabs-eyes before dissolved will soon fall to the bottom, and shew that such a solution was not water. (3.) These acids also agree in this, that in dissolving their respective subjects, they not only concrete with what they dissolve, but also have their own nature changed thereby. Thus we learn from experiments, that even the strongest acids, by acting as menstruums, are changed by the bodies acted upon; and not only lose their acidity, but their dissolving power. So, for example, when spirit of nitre dissolves mercury, till saturated therewith, the liquor drawn off is so changed thereby, as to be able to dissolve no more. (4.) It is also a common property of acids, to change the colour of vegetable juices, or to turn them red; as we see in the juices of violets, roses, turnsol, &c. (5.) They all agree in this, that they do not so much change the bodies they dissolve, as they are changed by them; which appears in numerous instances. Thus vinegar does not remain vinegar in the lead it has dissolved; nor is separated from it again in the form of vinegar: whereas the lead, upon reduction, turns to lead again. When spirit of nitre dissolves mercury, the mercury may thence be recovered perfect; but the spirit of nitre, separated from it, is no

The agreement of acids.

B b b b

longer

Their differences.

longer the thing it was before: 'tis therefore common to them all, that many of their acid parts are constantly lost in the act of dissolving.

18. These acids, however, differ considerably from one another; viz. (1.) In the quantity of true acid, with respect to the water they contain: thus, an ounce of the best vinegar holds but eighteen grains of true acid, the rest being water; an ounce of spirit of salt holds 73 grains of true acid, and the rest is water; an ounce of spirit of nitre affords 2 drams, and 23 grains of acid, and the rest is water; an ounce of oil of vitriol affords 4 drams and 65 grains of acid, the rest being water; according to the observations of M. Homberg (g). (2.) The several species of pure acids differ greatly as to the degrees of their solvent power. Spirit of nitre scarce touches gold, with a boiling heat, or only renders it black; but presently dissolves silver, whilst *aqua-regia* has the contrary effect: whence it is plain, that the acid here does not act in virtue of being an acid, but as a particular body. (3.) These acids also differ again in this, that some of them are changed in a different manner, or into a new substance, upon dissolving their solvends; some being thus changed more, and others less. The spirit of vinegar, by dissolving lead, becomes thick and unctuous; but spirit of nitre is not so much changed by dissolving the same. (4.) One and the same acid is greatly changed by acting upon some subjects, and little by acting upon others. Spirit of vinegar, we just now observed, is considerably changed by acting upon lead; but by dissolving iron quite loses its own nature, so as never to recover it; tho' by dissolving copper into a green liquor, whence crystals of verdigrease are obtained; these crystals contain a strong vinegar, separable from them by distillation with little change, tho' it adhered strongly to the copper. Whence we see, how great a difference may happen to an acid in different metals; which also holds of other subjects. (5.) All acids may be diluted with water, and united with spirits and oils: thus, spirit of nitre unites with alcohol, tho' not without conceiving great heat, discharging red fumes, and making a strong and almost fiery effervescence; the same spirit of nitre, upon uniting with oils, generally raises a violent heat, and sometimes a motion productive of fire and flame. Oil of vitriol also produces great heat upon mixing with alcohol. And when acids unite with oils, a bituminous, pitchy, or sulphureous matter is commonly produced; whence surprizing changes are made. And thus we finish our account of acid menstruums, with regard to their acting; and shall next proceed to neutral salts.

(g) *Mem. de l'Acad. Roy. de Sc. Vol. I. p. 52.*

S E C T. IX.

Of Neutral Salts, considered as MENSTRUUMS.

1. **B**Y neutral salts we here understand such as are neither acid nor alkaline, but seem to be a saturated mixture of the two. And first, comes common sal-ammoniac; which easily dissolves in water; and runs *per deliquium* in a moist air, so as thus to make an extremely pungent, penetrating liquor, capable of dissolving gross, gelatinous, pituitous, and gummy concretions in the bodies of animals; being not only admirably attenuating, resolving and inciding; but also sudorific, diuretic, and stimulating to the salival glands; and at the same time greatly preventive of putrefaction. So likewise, when this solution of sal-ammoniac is boiled, or digested, with gummy or resinous vegetables, it resolves them intimately, and thus disposes them to dissolve in aqueous or spirituous menstrua. It has likewise admirable effects upon metals. Thus iron-filings, by being boiled therein, are excellently dissolved and turned into an admirable, aperient and invigorating medicine. Being digested with filings of copper, it produces a beautiful blue liquor; a few drops whereof being taken upon an empty stomach, often prove good in case of worms and epileptic fits. This brine of sal-ammoniac is therefore an excellent menstruum, not only for animal and vegetable subjects, but also for minerals. *The dissolving power of sal-ammoniac.*

2. The pure dry salt being sublimed into flowers, and then very well ground and mixed with fossils, and sublimed together with them in close vessels, produces very extraordinary effects as a menstruum; whence it has been called by the alchemists the white eagle, or the philosophical pestil. If sulphureous bodies, metals, or semi-metals, be treated in this manner, they are thus attenuated, opened, volatilized, and perfectly changed. Whence most excellent remedies are in this manner prepared, and scarce so well in any other; as we see in making the flowers of *lapis Hematitidis, ens Veneris, ens Martis, &c.* The changes of colour produced in antimony, by being sublimed herewith, are very extraordinary: and many of the ancient chemists have called this salt, the key for unlocking the secrets of nature. It has this excellent property, that it is scarce changed in sublimation, except by the bodies it is mixed with. When added to *aqua-fortis*, or spirit of nitre, it presently turns them into *aqua-regia*. With fixed alkaline salts it soon changes, partly into a pure volatile alkali, which directly acts as such, and partly into a new salt, resembling sea-salt. A saturated mixture of the spirit of sea-salt, and a pure volatile alkaline spirit, immediately produces sal-ammoniac; which may also be made by subliming a mixture of sea-salt, urine, and soot: whence it seems to be a semi-volatile sea-salt: so that its power, as a menstruum, chiefly resembles that of sea salt. And on this account, it cannot be more improved than by being several times sublimed

Sea-salt considered as a menstruum.

from pure, dry, decrepitated sea-salt, in close vessels; which is the best method of obtaining the flowers of sal-ammoniac.

3. Though sea-salt, sal-gem, and spring-salt, differ in their origin, yet they are of one and the same kind, and may all be here considered under the head of sea-salt; which, by means of the sea-salt-spring, and salt-mines, is distributed over all parts of the earth, as the universal preservative against putrefaction. This salt easily dissolves in water, and runs *per deliquium* in a moist air, so as to make a brine, or an excellent menstruum, producing nearly the same effects in chemistry, as the above-mentioned brine of sal-ammoniac; and therefore may be used for all the same purposes.

4. Sea-salt decrepitates over the fire, and being afterwards reduced to fine powder, in a warm dry mortar, it may be melted in the fire; where it readily passes thro' the pores of the crucible, and vanishes. If semi-metals, or metallic fossils, are mixed with this salt in fusion, great and peculiar changes are thus produced. I mix eight ounces of moist, undecrepitated sea-salt, with two ounces of powdered antimony; and, after long grinding them together, I put the mixture into a crucible, and covering it with another crucible, I fastened them together with a strong luting; then setting them in a reverberating furnace for twenty-four hours, and increasing the fire at last to make the salt run, I found, upon opening the vessel, a dusky mass, with white spicula rising on the top; then reducing the whole to powder, I treated it as before, and obtained a ruddy mass, with the more metallic part at the bottom: and, upon repeating the process, and using a strong fire of fusion, almost all the salt passed thro' the pores of the vessel; leaving at the bottom a ruddy mass of antimony surprizingly changed: where we see, by an example, how this salt may act as a dry menstruum, by means of fire.

6. This salt may be used, on many occasions, with a much greater effect than any other salt; and therefore is usually applied, in a dry form, mixed with brick-dust, in the business of cementations, in order to introduce extraordinary changes as to the exaltation, separation and ripening of metals; which subject is largely treated of by *Paracelsus*, and verified by others. In this operation we are to observe, that the dry sea-salt, here mixed with the brick-dust, turns to a volatile acid spirit, resembling *aqua-regia*, and acting like that upon metals, so as to produce particular effects; and when, by this means, the sea-salt is turned to a spirit, and several times returned back upon a pure, dry, decrepitated salt, a surprizing particular solvent is thus obtained from the sea-salt: and, to this purpose, I shall here relate a laborious experiment.

6. To two pounds of spirit of sea-salt, I added, by degrees, as much pure, dry sea-salt, in fine powder, as the spirit would take up; then purifying the liquor by rest and straining, I put it into a tall, chemical phial; and inverting another of a smaller kind thereon, I carefully cemented them together; then exposed the matter to the heat of the sun, from the tenth of *May*, to the tenth of *July*. After this, I distilled it in a retort, with a gentle fire, till a thick liquor, appearing like oil, and containing hard crystals of sea-salt, remained at the bottom. What was distilled over, I now poured back, and drew off a-fresh, repeating this operation thrice: then found the salt remaining

remaining at the bottom was spongy, fat and oily. After this, I repeated the operation twenty times, and again poured back the liquor last distilled, and left them mixed together for five months; then with a gentle fire, I drew off an almost insipid phlegm, till the acid spirit began to rise; when, changing the receiver, and distilling with a stronger fire, I obtained an extremely strong, acid, ponderous oil of salt, which I kept separate, and observed, that the salt remaining at the bottom of the retort, after all these distillations, was extremely acid, and considerably fixed. I put this salt in a glass-dish, and exposed it to the air of a cellar, where it run *per deliquium*, into a liquor; which being purified by straining, and united again to the phlegm, spirit and oil of salt before drawn over, I thus at length, by a new distillation, obtained a menstruum of such efficacy, as made me not repent of my labour (b). This process I performed, in order to discover what truth there was in the account *Paracelsus* gives of it. Mr. Boyle, by means of a particular, long-continued digestion, obtained a spirit without phlegm, and rising before the phlegm, from sea-salt by it self; and this with the moderate heat of a sand-furnace (i). Sea-salt being dissolved, strained, purified, and crystallized, affords a ninth part of a saline substance, having a bitter austere taste, and not shooting into crystals; and this part being taken from it, the salt becomes the purer (k). These particulars being considered, it is no wonder that considerable chemists have attributed such great virtues to sea-salt chemically prepared; and this both in the way of a menstruum and a medicine: the method of preparing it for which purposes, may hence be learnt.

7. The common nitre, being produced from animal, alkaline and calcareous substances, is easily turned to fixed alkali, and a volatile acid. It also appears of a particular nature, when applied to bodies as a menstruum; and its operations are here so intricate, as sometimes scarcely to be explained, on account chiefly that the subject is extremely changeable by fire, and other things. When exposed to the fire, in a pure and dry state, it there soon flows with certain bodies, like water; and thence surprizingly promotes their melting, though otherwise of difficult fusion; and thus attenuates, divides, and intermixes their parts, even whilst it acts upon them in no other respect: whence it comes to be used in metallurgy, as a flux for metals.

8. But if the matter thus mixed with the nitre, contains any thing oily, unctuous or sulphureous, this suddenly deflagrates with the nitre in the fire, raises a violent flame, and greatly increases the heat; whence the application and action of the nitre being stronger, it greatly changes, divides, fuses, and separates the bodies in a different manner than is otherwise known; the nitre at the same time losing its own nature, or turning to a kind of *sal-polycrestum*, which has a different dissolving power from that of nitre. Whence the action of nitre upon bodies is of one sort, before it deflagrates with them, of another during the deflagration, and of a third after the deflagration is over.

9. Again,

(b) See *Paracels. Archidon. c. 4.*

(k) See *Du Hamel, Hist. Acad. Roy. Sc. p.*

(i) See *Boyle, Mechan. Orig. Qual. p. 234.* 16, 17.

9. Again, when nitre is melted along with a vegetable coal, its parts are, thus, strongly agitated, so as in like manner to agitate the bodies to be dissolved; at the same time discharging particular active fumes, capable of penetrating and dissolving many bodies in the fire. But, when the nitre is thus changed to fixed alcali, it does not flow, unless the fire be violent; and, then, according to its own penetrating and particular nature, it begins to act as a fixed alkaline menstruum; and thus acquires and exerts a new dissolving power: as we saw in the preceding account of alkaline menstrooms.

10. If the bodies thus to be dissolved, by fusion, with nitre, contain earth, stone, alum, vitriol, bole, or the like, the nitre is immediately changed into a strong acid volatile salt, or spirit of nitre: which, now, agitated with so violent a fire, penetrates, dissolves, and greatly changes the subject; thus acting by one of its parts, like *aqua-fortis*; whilst the other part remaining at the bottom, acts by a very different dissolving power. And, hence, we may understand, what a great effect this salt may have, when used in the way of cementation, along with metallic matters: for, thus it changes into a corrosive spirit, capable of altering metallic matters various ways; as may be learnt from the account above given of the acid tribe of menstrooms.

11. If pure nitre be fused in a strong fire, along with regulus of antimony, it at length produces a kind of caustic-stone, which acts after a manner, so far as I know, peculiar to itself; being a very fixed salt, of difficult fusion, and uncommon fiery acrimony. Whence, it appears what a prodigious dissolving power this salt may have, when mixed with regulus of antimony, and applied to bodies in the fire: doubtless its efficacy as a menstruum, must thus be extremely great.

12. If powder of sal-ammoniac be thrown upon nitre melted in a clean crucible, a gentle flash will be produced, as if a burning coal was thrown upon the nitre; whilst the salt is thus every moment changed in the fire, till at length, being saturated with the sal-ammoniac, it flashes no longer; but turns to a new kind of reddish-salt of a very particular nature, little known or considered by the chemists: but, whilst the nitre, and sal-ammoniac are thus mixed with other bodies in the fire, different kinds of solutions will be made at different times; and, consequently, different effects produced at each time, whilst the bodies remain together in the fire. These particulars are seldom carefully regarded by the operators; whence, they frequently meet with unexpected accidents, whilst they over-look such things as may alter the success of their experiments. If one part of sea-salt and two of spirit of nitre be distilled together, the liquor that comes over from them, with a gentle heat, will prove an *aqua-regia*, and act entirely as such; whilst the salt remaining behind, will be nitre; and, when thoroughly dried, act as nitre, at the end of the operation; tho', at the beginning thereof, it acted as *aqua-regia*, in the liquor distilled over. Whence, we see what a great difference there may be in the action of a menstruum, at different times of the operation. So, again, if one part of pure nitre, and three parts of the spirit of sea-salt be distilled together, they yield a strong *aqua-regia*; whilst the

the dry salt remaining in the retort, is, again, left true nitre. Which shews us how careful we ought to be, in the use of these menstrums, to prevent being imposed upon. So, likewise, if the spirit of nitre, with a proper proportion of any alcali, be used as a solvent, they soon turn to nitre, and act as such at the end of the operation. And, if *Glauber* says true, that nitre may be made from a mixture of sea-salt, fixed alcali, and quick-lime, burnt and ignited in the fire, and afterwards exposed to a moist air; these three substances, being used together in cementation, must have a very different effect from what one might otherwise imagine. All which being considered, and compared with what is above delivered of the conversion of nitre into alcali and acid, will sufficiently shew us the great and different power of nitre as a solvent.

13. Native borax, found in the *East-Indies*, *Persia*, and *Transylvania*, being dissolved in water, filterated and crystallized, has a somewhat sweetish and bitterish taste; but is neither acid nor alkaline. By strong distillation it affords mere water; whilst the part that remains behind, turns to glass, incapable of being dissolved in water. When mixed with sand, and urged with a violent fire, it affords no acid spirit. It greatly promotes the fusion of metals, and unites them together in fusion: and thus, also, has numerous other effects, which could not otherwise be so easily obtained. *Borax as a menstruum.*

14. If what is above delivered of saline menstrums be well understood, it will not be difficult to conceive that various combinations of salts should produce many new kinds of saline menstrums, having singular and uncommon dissolving powers. These combinations are sometimes made by art and contrivance, and sometimes accidentally, so as to surprize by their unexpected effect; and, thence, come to be registered in books of chemistry: and, from these two origins proceeds that vast stock of menstrums which chemistry abounds with. Thus, when volatile alcalies are mixed with the fixed kind, the former are always rendered stronger and more volatile by the action of the fire; whilst the latter, attracting the acid particles, the oil, or earth, which may remain in the volatile alcalies, hence become different, or more compounded and productive of other effects. Fixed alcalies being united with native vegetable ashes, afford an extraordinary compound salt, of a mild, aperient, and diuretic nature; as we see, upon mixing salt of wormwood with juice of lemons, &c. in a proper proportion; whereby a salt is procured, of very different dissolving powers from the parts it was composed of, or from any other salts: and, when volatile alcalies are mixed with these acids, another kind of compound salt is produced, differing greatly from the former made with fixed alcali. When fixed alcalies are properly united with pure, fermented vegetable acids, they, upon mixing, afford many extraordinary phaenomena, and produce a neutral, mild, volatile, penetrating, saponaceous salt; which easily melts at the fire, and has considerable virtues. Thus, salt of tartar saturated with distilled vinegar, or with crude tartar, produces an excellent neutral salt; the effects whereof, upon animal, vegetable, and fossil substances, have made me sometimes suspect it to be the volatile salt of tartar, so highly extolled by *Helmont*. And, perhaps, of all the neutral tribe of menstrums, there is not one *Compound saline menstruum.*

one that more deserves to be considered, and made use of, than this, as might be shewn by numerous examples; and, as remarkably appears by its dissolving the body of myrrh, which difficultly yields to alcalies and acids, so as to be rendered potable and miscible with the blood: but, by being properly digested with this neutral salt, it is intimately, and inimitably dissolved for the purpose. And the same salt, if carefully made, intimately unites with spirit of wine; so as to afford a menstruum which every one that makes will find his labour sufficiently rewarded. And, hence, we might easily confute the error of the modern chemists; who, making acids and alcalies the principles of all things, pretend it betrays unskilfulness in chemistry to mix acids and alcalies together; as if the virtue of each were destroyed by the mixture; and no useful property left behind: an argument strongly insisted upon by *Zwelfer*. On the contrary, it is certain, that the pure alcali of tartar, properly mixed with the volatile acid of vinegar, makes a neutral salt of a much more noble virtue than the separate acid or alcali. And, when a pure volatile alcali is exactly saturated with the strong spirit of vinegar, we have thus a limpid, lightly saline, volatile, compound liquor, of such a peculiar dissolving virtue as is not otherwise to be met with: as being able to pass thro' almost all kinds of bodies, so as to dissolve them, without any considerable visible conflict. Whence, some physicians have highly esteemed this liquor, in curing disorders in the eyes, and ears, arising from any concretions formed therein. And, on the same account it has been held a great and successful secret for resolving cold, glandulous swellings, to foment them with a mixture of putrescent urine and vinegar; the part being first rubbed, and the liquor applied warm.

15. And from hence we may understand what will be the consequence of mixing either fixed, or volatile alcalies with fermenting acids; viz. the stoppage of the fermentation in hand, after the production of a sudden effervescence, and the consequent production of neutral salts, like those just now described. And the like neutral salts will also be produced, upon mixing the same alcalies with the acids obtained either by distillation, or the burning of woods in the fire.

16. When these fixed alcalies are united to a native fossil acid, new compound salts, greatly differing from one another, are produced. Thus, for example, if hot oil of tartar *per deliquium*, be gradually dropped upon a solution of pure alum in water, till the point of saturation is obtained, an earthy calx will be precipitated: and if the clear liquor floating about it, be filtered, the native acid of the alum, here attracted by the alcali, will afford a salt like tartar of vitriol, but without any metallic part, and of an excellent dissolving power as a menstruum, and of considerable medicinal virtue. So again, if to a warm and clear solution of white, green, or blue vitriol, the same solution of fixed alcali be added, after the same manner; we hence obtain a compound salt, consisting of the fixed alcali and the fossil acid, which had dissolved the calcareous matter, the iron, or the copper, naturally dissolved in the vitriols: whence, again, a neutral tartar of vitriol is produced, differing from the common in this, that its acid had not felt the force of so strong a fire; and, therefore, better preserves its native virtues

tues: it, also, better deposits its metallic parts, except the vitriol was from copper, whose metallic part remaining in the solution, tinges the salt of a blue colour.

17. When fixed alkali is intimately mixed with sulphur, the fossil acid of the sulphur is attracted into the alkali: and, hence arises a salt resembling the former, tho' of a somewhat different nature; as appears by the figure of the crystals it shoots in: which seems principally to rise from hence, that the unctuous part, mixed in with the sulphur, also joins itself to the fixed alkali, and fouls the salt; thus making a more compound salt, of different odour, taste and virtue.

18. Hence also, we may learn what will be the consequence, upon mixing vitriolic, or aluminous waters, or their unctuous sediments, however procured, with fixed alkali: for, thus the metallic or terrestrial part, held dissolved in them, being now separated, the acid solvent will unite with the alkali into a kind of *tartarum vitriolatum*, where the dissolving power is peculiar or different from that of other salts; as appears by applying it to metals, semi-metals, sulphurs, and other fossil substances. And, this salt usually retains its dissolving power more permanently and immutably than any other compound salt; its acid, as well as its alkali being more fixed, and both, thus united into a very fixed neutral salt. Nor, do we know any other acid, which, when applied to this tartar of vitriol, is able to separate the acid it contains: whereas the native acid of vitriol, commonly expels the acid from all other salts; as we saw above.

19. When pure volatile alkaline salts are mixed with these native fossil acids, a particular kind of ammoniacal salts are thus produced, composed of the fossil acid, and volatile alkali; and these, for distinction's sake, may be called by the name of semi-volatile tartars of vitriol. These ammoniacal salts highly deserve to be regarded by chemists, as menstruums, on account of their remarkable dissolving property; and, by physicians, on account of their considerable, aperitive, attenuating, resolving, stimulating virtues.

20. Hence, also, may be understood what will follow, upon mixing common sal-ammoniac with the vitriols, and committing the mixture to the fire; for, thus, the acid of the vitriols, being attracted into the acid part of the sal-ammoniac, releases the acid spirit of the sea-salt, which makes the other part of the sal-ammoniac: and, this spirit being volatile, is thus separated, whilst, by the union of the vitriolic acid with the alkaline part of the sal-ammoniac, a semi-volatile tartar of vitriol is produced; the remaining part being a metallic mass before contained in the vitriol, but, now, precipitated in the form of fæces; or else, being again dissolved by the spirit of salt, affords a new kind of metallic solution. And, hence, we have a just foundation for judging of the event of combining, fixed, or volatile alkalies with all the native fossil acids, however they may lie concealed in metals, earth, oils, or other salts; for the effect will here be always the same, and may be predicted from what is above delivered. And these experiments are so certain, and, consequently, so agreeable, nay, and so useful both to chemists, and physicians, that they cannot be sufficiently recommended.

*Menstruums
from fixed al-
kalies, and
distilled fossil
acids.*

21. The doctrine of menstruums next requires us to consider those which arise from the combination of fixed alkalies, with a fossil acid obtained by fire. When pure fixed alkali is perfectly saturated with the acid spirit of sea-salt, sea-salt itself seems thus, in almost all respects, to be regenerated. When saturated with the acid of nitre, it re-produces nitre; and, with the acid of alum, and, the acid of sulphur, or vitriol, it constantly makes the *tartarum vitriolatum*, as above described. In the same manner, when pure volatile alkali is united with spirit of sea-salt, there arises a true sal-ammoniac; and when mixed with spirit of nitre, *aqua-fortis* or a semi-volatile nitre is thus produced. If the same volatile alkali be united with oil of vitriol, *oleum sulphuris per campanam*, or with the acid distilled from alum, it thus produces a semi-volatile tartar of vitriol. All which makes it appear, how many and what surprising actions of menstruums may frequently arise from the bare mixing of certain bodies together, and applying them thus mixed to the fire. It is almost incredible, how great a change may proceed from the mixture of one single thing with another, either by art, or accident. And without an exact knowledge of all these particulars, we can never have an adequate knowledge of the chemical history of menstruums.

*Menstruums
from mixing
simple salts
with others.*

22. We now proceed to consider the action of menstruums made by uniting pure simple salts with other salts: for which we have already prepared the way. Thus, if pure alkali be added to the brine of sea-salt, an earthy matter is precipitated; and the salt now obtained by crystallization from the clear liquor, will be purer sea-salt. The same fixed alkali being added to a brine of nitre, changes the liquor thick and milky; and precipitates an earthy matter, whereby the nitre obtained from this solution becomes extremely pure. When fixed alkali is added to the brine of sal-ammoniac, it lays hold of the acid of that salt, sets the volatile alkali free, or suffers it to fly off into the air; leaving a pure, fixed sea-salt at the bottom of the vessel. If a pure, volatile alkali be added to the brine of sea-salt, it makes the liquor thick, then purifies it and flies off: and, it does the same, when added to a solution of nitre. When added to a solution of sal-ammoniac, it in like manner purifies the salt, without altering its nature; and flies off as it was poured on. Vegetable acids produce but little alteration by being mixed with sea-salt, nitre, and sal-ammoniac. Fermented vegetable acids, even after being purified by distillation, produce no great alteration when mixed with the same salt. As for the changes arising in the menstruums made by an artificial mixture of fossil acids with these salts, we have mentioned them above, in treating of those acids and those salts; where we saw, that a strong fixed acid copiously adheres to calcined alum and vitriol; the particular effect of which acid, when actuated by fire, is to expel all other acids from the bodies they had dissolved; provided such bodies are dissolvable by the acids of alum, vitriol, or sulphur. Hereof we have already produced examples; and shall only add, that, if quicksilver be incorporated with calcined vitriol, by long grinding them together, and decrepitated sea-salt be added thereto, and the mixture be put to sublime in a glass-vessel, with degrees of heat, in a sand-furnace; the acid of the vitriol thus turns the acid of the sea-salt into a spirit, which now dissolves the mercury,

mercury, and makes it rise to the top of the vessel, in the form of pure mercury-sublimate: which is no more than the spirit of sea-salt attracted into the quicksilver; and thus united therewith, into an uniform vitriolic, mercurial mass, soluble in water. There are numerous surprising instances of this kind, in the history of menstruums; which may all be understood by the principles here laid down. Thus, for example, if calcined vitriol, or alum, be mixed with nitre, and distilled, they yield *aqua-fortis*, which contains nothing of the acid of vitriol, but is a pure spirit of nitre; and, if mixed with sea-salt, and treated in the same manner, they make spirit of salt; if, with nitre and sea-salt together, they make *aqua regia*. So, if nitre and calcined vitriol be melted together, in an open fire, the acid of the nitre is discharged, and a kind of *tartarum vitriolatum* left behind. Sea-salt treated in the same manner, leaves a kind of *Glauber-salt* behind. But it will be more agreeable to solve phænomena of this kind for one's self, from the doctrine here delivered, than to have all the particulars pointed out. Let it only be remembered, that in what way soever salts are united with salts, new saline productions, and new menstruums will arise; whence, the art of chemistry may perpetually be improved, and new phænomena produced: the consideration whereof may, not only afford pleasure to the mind, but increase our knowledge of the native properties of bodies, and often lead to great and unexpected discoveries for the accommodation of life.

32. In the last place, it will be highly necessary to remember, that new *New menstruums* menstruums of particular virtues may be made, by variously combining different menstruums together; which may be done, almost, infinite ways: again, by reducing every menstruum to its utmost degree of purity; and lastly, by reducing some of them into the minutest particles they possibly can be, either by nature or art: for, upon these three particulars, the extraordinary skill of the chief chemists seems principally to depend. It would be endless, to give all the instances that might be produced to this purpose; we shall content ourselves with the following, for the present. Suppose, an extremely pure, strong, and subtile, fermented, vegetable acid was wanting: take fine verdigrease prepared from copper, corroded by the subtile vapour of a fermenting acid; add to it, twenty times its own weight of the strongest distilled vinegar that can be made, digest them together, till the verdigrease is dissolved into a deep-green liquor; which being thoroughly purified by filtration, and inspissated over a gentle fire, to a pellicle, set it in a quiet place, where it will shoot into crystals, of the colour of an emerald, consisting of the acid of the vinegar and the dissolved copper; pour off the liquor, collect the crystals, and, again, evaporate as before: set this liquor to shoot, collect the crystals, and repeat the process, till no more crystals can thus be obtained. If, now, the verdigrease, saturated with the acid, be dried in a warm air, then distilled in a glass retort, with degrees of fire; you may obtain a most pure, and perfectly strong, vegetable acid, no way participating of the copper. But, the same experiment does not succeed with lead, tin, or iron; whereas, copper thus attracts the acid separately from the aqueous part, and without changing its nature; whilst other

Substances would also attract and separate it, but at the same time, render it impure. A vinegar, for this purpose, may be made from beer, cyder, perry, honey, sugar, manna, &c. and thus be brought to afford a strong vegetable acid, by means of copper: which acid, *Zwelfer* imagining to be the alcahest, he is corrected by *Tacbenius*, who shews it to be no more than a strong distilled vinegar.

24. But there is no end of discovering new menstruums; every artist usually boasting of his own particular secret solvent; whereby he is commonly able to perform what another cannot, without knowing the particular menstruum. And with regard to this affair, I rather blame the reservedness of artists, than the oddness of their menstruums: for, every person who is skilled in chemistry, may for ever discover new menstruums, by the artificial application of body to body: so that, the proper menstruums for all substances might, perhaps, have been discovered; and, consequently, a solvent for the stone; if chemists, for this purpose, had properly tried all the liquors they have prepared. Suppose, any chemist had carefully examined all menstruums, except the spirit of bread; he could not easily believe what a power that menstruum has in dissolving several bodies.

25. To shew, that by compounding one menstruum with another, new, and often excellent salts may be procured; let it be recollected, that regenerated tartar, properly prepared, may be intimately united with pure alcohol, and thus produce a vegetable menstruum, composed by the close union of the most subtile vegetable particles; viz. alkali, acid, and sulphur: whence, the effect of such a liquor is extremely great, both as a menstruum, and a medicine. So, again, if a pure, strong, alkaline spirit, be united with pure alcohol, it produces an admirable menstruum, or the *ossa Helmontii*, which intimately dissolves distilled vegetable oils; and, thus, makes a menstruum compounded of the genuine, vegetable sulphur, and alkali; and is one of the most excellent menstruums and medicines hitherto known. In like manner, pure spirit of nitre, saturated with the alkaline spirit of sal-ammoniac, makes a kind of volatile nitre; and, thus, affords us an opportunity of examining, by experiments, whether it will perform the things expected from the volatile nitre, so much enquired after. Many chemists have spent their lives in making experiments of this kind; being pleased with the discovery of something new, as a reward of their labour. And, such experiments may well deserve to be prosecuted; the discoveries being, all along, carefully observed: for when a number of them are carefully digested and considered, more general rules may be formed about them.

Consequences
from the history
of menstruums.

26. It is time we should now proceed to draw out the consequences afforded by the preceding doctrine of menstruums; and, (1.) It is not certain, whether any menstruum has a power of dissolving any subject, without the assistance of fire; as no experiment could ever be made in a place destitute of all fire; since we saw, in our account of the utmost known degree of cold: and especially, since most of the known menstruums act the better when assisted by a certain degree of fire.

27. (2.) Menstruums can scarce act as such, unless reduced to a fluid form, or at least approach thereto; as they chiefly do, by the means of fire, air, water, and triture; which four causes usually excite the latent powers of menstruums.

28. (3.) Certain menstrooms contain a cause within themselves, apparently capable of exciting motion; tho' in reality it depends upon the near approach of another body: thus, if a good load-stone be suspended by a thread, and hangs at rest in a great degree of cold, it will seem to have no active virtue; but, if iron comes near it, a motion is produced in both these bodies, till they come together, and remain in contact: and this kind of power generates motion spontaneously, without the assistance of any fire sensible to us; and is not excited by motion. So, likewise, strong spirit of nitre, confined in a close vessel, yields an acid fume, constantly playing above the surface of the liquor, and issuing out whenever the vessel is unstopped. So, likewise, the alkaline spirit of sal-ammoniac yields a fume, which I could never observe to be at rest: and the spirit of sal-ammoniac made with quick-lime, yields a fume much more volatile and moveable. Such kind of bodies, therefore, strangely retain, and strangely excite motion: and, possibly, there are such continually floating about in subterraneous places, till they rest in some one body where they unite, fix, and thus produce numerous compound substances. But, we are always to remember, that air, even in the utmost cold, has a constant vibratory motion; and, therefore, may often excite the motions we here speak of; as, on the other hand, solutions are often immediately performed by means of the motion peculiar to the menstruum arising from it; whilst a considerable motion of another kind, and proceeding from a different cause, would not produce the effect. Thus, for example, if a piece of fine *English* chalk be calcined in a strong fire, or even in the focus of a burning concave, it will scarce be changed by this violent motion; nor, again, by being exposed to a hot or cold air, either at rest, or agitated by strong winds; and, tho' it long boiled in water, or a brine of salt of tartar, it will not dissolve; but it immediately melts and disappears in cold vinegar: whence, we see there is a very great difference betwixt the motion excited by the reciprocal force of the solvent and solvend; and the motion excited by fire, air, water, and impulse.

29. (4.) The acrimony of a menstruum, with respect to the human body so as to excite pain, corrode, or consume the parts thereof, is no sign, that such a menstruum is suited to dissolve other bodies; as appears from oil of vitriol, spirit of nitre, spirit of salt, and *aqua-regia*: which, tho' they readily consume flesh, yet do not dissolve wax and sulphur; tho' these two may easily be dissolved in the body.

30. (5.) Many bodies, incapable of dissolving in certain menstrooms, may be fitted for dissolving therein, by being previously dissolved in another menstruum. Thus, if common sulphur be boiled ever so long in alcohol, it dissolves no more than a stone in water; but, if the sulphur be first melted with salt of tartar into a dusky mass, cold alcohol will soon dissolve the sulphur intimately. So, likewise, powdered antimony will not dissolve by boiling in alcohol; but, if first boiled to a dry mass, with an alkaline lixivium, this mass presently yields a golden tincture with alcohol. Some eminent chemists have conceived so highly of this regular and successive application of different menstrooms; particularly, Mr. Boyle, and M. Homberg;

that

that they say, even metals may, by this means, be resolved into their component running mercury, and fixing sulphur. Thus they assert, that if silver be first dissolved in spirit of nitre, then long digested with pure, fixed alkali, and afterwards several times sublimed with sal-ammoniac, it will at length, by means of these resuscitating salts, afford a true running mercury: in which operation the acids procure an entrance for the fixed alkalies, into the substance of the metals; as the fixed alkalies procure admission to the volatile alkalies, which could not otherwise enter. If my sentiments should here be asked, whether metals may, in this manner, be turned to mercury? I can only answer, that, after making many experiments with this view, I have not found they could.

31. (6.) Certain menstruums dissolve such bodies as before trial might be judged little suited thereto: and this holds both on the side of the solvent and solvend. Thus the viscid and tenacious body of native turpentine, is so penetrating in the body, as very soon to give a violet-smell to the urine, change its colour, and warm the person who takes it; it dissolves oils and rosins with a gentle heat, and even the gummy rosins, such as gum-copal, which can scarce otherwise be dissolved. The yolk of an egg would scarce be suspected of any solvent power, from its obvious properties; yet, by being ground with any of the gums, oils, rosins, or balsams, it dissolves them better than any other menstruum; destroys their tenacity, renders them miscible with aqueous and spirituous liquors, and fit to enter the circulating fluids of animals: whence we have an example of a menstruum, prepared by nature, an equal whereto scarce any art can furnish. So likewise the bile of animals, especially that of fish, has a similar power of dissolving balsams, gums, rosins, turpentine, &c. Manna, honey, and sugar have also the same effect. The white of egg, when boiled to hardness, and distilled in *balneo Mariæ*, affords a limpid, aqueous liquor, of no considerable smell or taste, and of no saline, acid, or alkaline nature; yet, what a particular power it may have, even upon metals, appears from *Paracelsus* and *Helmont*, who judged it the properest thing in preparing their medicated mercury. And if the white of egg, after boiling, be suffered to run *per deliquium*, in a cellar, it turns to a kind of pure water, which dissolves the hard, tough substance of myrrh, better than any other menstruum. It must needs appear strange to those who are not versed in chemistry, that even the mildest things should dissolve such bodies as scarce any other menstruum would touch.

28. (7.) Hence therefore acidity, acrimony, or a saline property, discovered in any menstruum, can never assure us, without trial, that such a menstruum will dissolve a given substance; or, till we find, by particular experiments, that a solution ensues, upon putting the bodies together. Thus, if any known acid, whether strong or small, be put to common sulphur, and assisted by heat, it will not dissolve the sulphur. So spirit of nitre, which dissolves the other metals, will not touch gold: whence we cannot safely say in general, that acids dissolve metals; but properly, that certain acids dissolve these or those particular metals. A person who had often experienced the corrosive virtue of strong fixed alkali, in numerous substances, might perhaps expect it would dissolve all bodies; but he would soon be undeceived, upon finding

finding it does not affect quicksilver, gold, or silver. And the same holds also of salts. Silver is whitened by being boiled with cream of tartar, but not at all by sea-salt. Hence we cannot say, that acids, alkalies, or salts are solvents universally; but only with respect to their determinate, definite subjects, whereto nature has fitted and limited them.

29. (8.) So again, conversely, a cautious chemist, finding a body to be dissolved, will not infer that an acid, an alkali, or a neutral salt, was the cause of the solution, unless other circumstances determined this to be the case; yet the modern chemists have often deviated from this rule, through a fondness for general conclusions; inferring the solvent to be known from seeing the solution. Suppose a person sure, that gold was dissolved into its least particles, and that there was no other known solvent of gold besides sea-salt, or preparations thereof; yet he could not hence justly infer, that sea-salt was here the solvent: for pure quicksilver will also dissolve gold; tho' quicksilver be as far from an acid, alkaline, or acrimonious saline nature, as any of the known substances.

30. (9.) We may go farther, and say, there is no such thing as a general or absolute corrosive, or dissolving acrimony, this being always relative, and holding only true of the solvent and solvend, and not of the solvent, in respect to all other bodies. Thus, if upon seeing the corrosive virtue of *aqua-fortis*, in a thousand instances, upon animal, vegetable, and mineral substances, we should hence conclude it would corrode all other soft and tender substances; we might soon correct our selves by observing, that it will not dissolve soft wax, or brittle sulphur.

31. (10.) On the other hand, it is no safe conclusion, that because a menstruum proves mild and innocent to the human body, it will not therefore dissolve other bodies: for oil-olive may be safely received, in a large quantity, into the stomach and intestines; tho' it readily dissolves sulphur and wax, which acids will not touch. Melted wax, though so mild a substance, is said to extract the red colour of coral, which long sustains a violent fire without changing, and even resists the force of alkalies; but we could have no information hereof, unless the experiments had been made. Hence the hardest bodies, with regard to our senses, and found to be such by their resisting of fire, do not require, in order to their solution, solvents apparently corrosive.

32. Upon the strength of the doctrine here delivered, it cannot appear impossible to discover, in art or nature, a peculiar menstruum, capable of dissolving some one thing insoluble by almost all others; whilst, at the same time, this same solvent shall not dissolve other substances of a much weaker or softer texture. And the way of discovering such a menstruum, is by successively applying all sorts of menstrooms to the body whose solution is required; and here what might be judged the least proper for the purpose, may sometimes best answer the end (*b*). Thus, for example, though cancers and the stone in the bladder have hitherto proved incurable, yet we ought, on no account, to despair of discovering remedies for them; and particularly of

(*b*) One can scarce help observing, upon this occasion, that the strongest fixed alkali, rejected by the author in some parts of this work, as no cure for the stone, should, upon experience, appear to be a safe and true solvent for the purpose.

of finding a method of dissolving the stone, without hurting the bladder; since it is, by no means, a consequence, as we have seen above, that the bladder should be corroded by the same remedy which dissolves the stone (i).

33. The spirit of rye-bread has a surprizing power to dissolve certain stones; yet does not corrode any parts of the human body: and the water, which boiled whites of eggs spontaneously run into, dissolves many substances; yet may be poured into the eye with safety.

34. (11.) Most menstruums, at the time they dissolve and change the subject, are also changed thereby; the action being reciprocal; as appears in almost every menstruum we apply: and tho' water, alcohol, and mercury, hence receive but little alteration; yet they usually are gradually changed by the operation. Pure mercury, indeed, is said not to be altered in solution; yet, upon being mixed with other things, it is changed in concreting, and frequently rendered less pure, or altered considerably; and this even when turned to a metal.

35. (12.) It is a great error to suppose, that the purer any menstruums are made, the more powerfully, or the more perfectly, they always dissolve; whereas, on the contrary, their dissolving power is often diminished, in proportion to their purification. Thus, lead is always more difficultly dissolved in *aqua-fortis*, the stronger the *aqua-fortis* is made; and, more easily, when the menstruum is diluted with a proper proportion of water. So, iron cannot be dissolved in strong oil of vitriol; but easily, if that oil is weakened with four times its own quantity of water. Alcohol coagulates many bodies which common brandy will dissolve; as we see in blood, which is taken up by brandy, but condensed by alcohol: whence it is plain, that the utmost purity and simplicity of a menstruum does not always increase its dissolving power. On the other hand, the utmost purity is often required in a menstruum, to make it a proper solvent: for example, distilled oils require perfect alcohol to dissolve them totally, into an uniform liquor; the interposition of water preventing the effect: so likewise amber requires perfect alcohol to dissolve it, and will not yield to brandy. Hence we cannot absolutely pronounce of menstruums, without trial, whether they should be weak or strong, in order to dissolve certain subjects; but the matter must be determined by experiments.

36. (13.) There is nothing more remarkable in this doctrine of menstruums, than the production of new powers by their action; which powers before existed neither in the solvent nor solvend, but depend intirely upon the union of both, after the solution is performed. For example, an infant might safely swallow a few grains of quicksilver, or a very few drops of spirit of salt; but if these two bodies are united, so as to make corrosive-sublimate, three or four grains thereof would prove a violent poison. So again, 30 grains of crude antimony in powder, might safely be given to a child, and as many of nitre; but if these two are mixed and deflagrated in the fire, they instantly

(i) What is here judiciously mentioned by the author, as to the possibility of discovering a safe solvent for the stone, might dispose one to examine the merit of any supposed solvent for the purpose. And I should hope, from a careful examination, that mankind are to be congratulated upon the late happy discovery

of such a real solvent, in a safe, internal, alkaline remedy: which affords a noble subject of chemical enquiry, not hitherto prosecuted as it deserves; nor capable of being enter'd upon, with public advantage, till the doctrine of menstruums shall be more generally known.

instantly produce the *crocus metallorum*, six grains whereof no man would venture to give a child; as that dose might prove mortal. And chemists being thus admonished, will, it is hoped, not always expect, that the productions of their solutions must needs be either innocent, or medicinal, only because the simples employed therein were so. Great mischiefs, and a high disgrace to the art, arise from this injudicious reasoning of the chemists; and nothing has astonished me more, than the insufferable liberty with which mere operators, without any knowledge of physic, have been bold enough to ascribe medicinal virtues to every production of their art: a flagrant instance whereof we see in *Rasul Valentine's* triumphal carr of antimony. I have often thought, that a carpenter, a statuary, or any other artist, might as well bestow extravagant praises upon the work of their own hands, as a chemist. Whoever has regard to truth and virtue, will think this licence should be prudently restrained; and that, if any new production be thought deserving of a trial as a medicine, it should be done slowly and carefully; beginning with a moderate dose, and having the mind intent upon the event and circumstances. And thus, our chemical doctrine of menstrooms may lead us to understand all the best and greatest discoveries which the art is able to make. For, by considering the several classes of menstrooms above described, and the proper subjects assigned to each class, with the genuine marks annexed, such rules may thence be formed, as will, in some degree, enable us to foretell the consequences of applying one body to another; tho', I judge, we shall always find, that new and unexpected events will arise, in making the experiments. It gives me pleasure to have said thus much upon the noble subjects of menstrooms; tho' there is still another article to be considered, under the title of the alcahest.

S E C T. X.

Of the Alcahest, or Universal MENSTRUUM.

i. **U**PON carefully considering what is above delivered, it should seem as if all the chemical solutions, except a few which are merely mechanical, are the effect of a latent attraction, and repulsion, betwixt the parts of the solvent and solvend; and consequently, that the whole action depends upon a certain relation betwixt these two. And hence it follows, from the known rules of the art, that there is no one body, either natural or artificial, which can universally dissolve all the rest. And farther, it seems impossible to assign any one physical manner, wherein the solution of all sorts of bodies should be performed indifferently. But after the elder *Helmont* publishing his writings, chemists had a notion of a certain secret menstroom, of which *Paracelsus* was said to be master; and which, after this usual manner of coining names, he called the alcahest; and this, if ever known to any man, as *Helmont* solemnly affirms it was, must be esteemed the most valuable discovery ever yet made in chemistry; or any other art; as

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being of greater consequence, and more to be desired than the philosopher's stone; as, by means of this alcahest, the most effectual remedies, and the greatest opulency might easily be procured. This was the judicious opinion of Mr. Boyle, who in vain employed the greatest pains and skill to find it out; but yet, in his judgment, he scarce seems to have believed there ever was such a thing. Many eminent chemists have wrote largely upon this menstruum, after *Helmont*, as of a thing they knew. Impostors have made their advantage of it, and tricked those out of their money who were eager to learn the secret; whilst the prudent have remained in doubt, without speaking definitively about it. This has determined me to give a faithful historical narration of the matter as it stands, so far as I can learn its history from the writings of those who have treated upon the subject; in order at least to discover the sentiments of such among them, who declare they have possessed and used it. But, I find, that all the later authors have only copied from *Helmont* upon the subject. As to what *Paracelsus* says of the alcahest, no one could have thence thought of such a thing, if *Helmont* had not intimated that a mystery was concealed under so quaint a term. And as I myself do not possess the secret, all that I can possibly do is only, by a strict examination, and exact comparison of these writers, clearly to explain the matter, so far as I could discover it in them; for if they knew such a thing, and designed that a careful reader should find it in their writings, I cannot think of a better way than this for coming at it. Whoever, therefore, would undertake the task of preparing such a menstruum, should know upon what materials, with what instruments, and in what way to operate, that his labour may not be lost. But here it is of the last consequence to prevent being imposed upon by the tricks of strolling alchemists; who, with their importunate pretences, and insinuating address, promise they know not what. These vagabond alchemists may easily be detected by any one who understands the doctrine of *Paracelsus* and *Helmont*; which has often been of great assistance to me, when I had such noisy, ignorant pretenders to deal with. Let us therefore examine the matter with care.

The term.

2. The word alcahest is mentioned by no writer, not even among the chemists, before *Paracelsus*; who, so far as I can find, mentions it only in the following passage, viz. (a) "The liquor alcahest has a great effect upon the liver, so as to fortify and invigorate it, prevent the dropsy, and all diseases which happen to that part. Its process is, to resolve it, after it is coagulated, and then coagulate it into a transmuted form; as its process of coagulating and resolving shews. Then if it conquers its like, it becomes a medicine exceeding all others for the liver: and though the liver were consumed, this liquor serves instead of the whole liver, as well as if that part had not been consumed. Wherefore, all those who practise physic, should know how to prepare the alcahest, in order to cure numerous distempers arising from the liver." *Paracelsus*, therefore, has here only used the word twice, and does not use it in any other place; as I have found by carefully examining all his works. Whence no one would have had any farther

(a) *Paracels. de virib. membror. L. II. c. 6.*

farther thoughts upon this subject, if it were not for *Helmont's* subsequent interpretation.

3. The origin also of this new term, coined by *Paracelsus*, has been en- its etymology.
quired into: and, as his manner was to disguise the words he used, by trans-
posing the letters thereof, some have imagined he here practised the same art;
and thus sometimes also, by joining the initial letters of words, he has form-
ed such as were unheard-of before: so when he means to mention tartar, as
a remedy to open the spleen, he calls it *sutratar* (b). Again, when he di-
rects saffron, (which, on account of its yellow colour, being called *aroma*
philosophorum,) in diseases of the kidneys, he calls it *aroph* (c): and hence some
have thought, that *alcahest* signified the same as *alkali est* (d), as if its basis
were an alkali, saturated with a proper acid. Others have imagined, it was
called *alcahest* from *Salz-geist*, or the spirit of salt; as supposing the *alcahest*
the same as the *Ciculatam*, and prepared from sea-salt, coagulated, resolved,
and again coagulated into a transmuted form. There are others who suspect
it is called *alcahest*, in allusion to *algeist*, that is perfect spirit, made by coa-
gulation, resolution, and a second coagulation; which agrees with the opi-
nion of *Faber*, who takes it for a pure mercurial or metallic spirit, so united
to its proper body, as thence to become one inseparable and indestructible
substance (e). But, as we can find no certainty from the etymology, let us
pass on to the synonymous words; and try if any light can be gained by com-
paring them together.

4. *Paracelsus* has given us no synonyma, that I can find, to the *alcahest*; Synonyma's.
but *Helmont* a considerable number: and indeed, we have no assistance in
this affair but from *Helmont*, who professes the *alcahest* was given him.
Helmont, therefore, first calls it simply water, and says, he "knew a wa-
"ter, which he did not think proper to discover, by means whereof all ve-
"getables might be transmuted into a liquor, capable of being distilled,
"without leaving any fæces behind (f). He declares, he put equal quan-
"tities of a certain water and charcoal into a glass, which he hermetically
"sealed, and set to digest in a bath-heat (g)." In this passage, he calls
the menstruum a thicker water (h); and says, that in the first chapter of
the second book of the *Maccabees*, mention is made of a thick water, which
was perpetual fire, and perhaps not unlike his water. In another place, he
calls it a dissolving water; and says, the liquor *alcahest* is an immutable, dis-
solving water (i). He comes nearer to the purpose, when he calls it by a com-
pound word, *ignis-aqua*, fire-water (k). Where, giving an allegorical account
how he came by his knowledge, he pretends he received a phial, in which was
the single term *ignis-aqua*, a perfectly simple, singular, undeclinable, immu-
table, and immortal word. He also calls it a *latex*, or clear water, reduced
to the minutest possible atoms (l). He frequently calls it a liquor (m).
He asserts, that by applying the liquor *alcahest* of *Paracelsus*, all bodies may

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(b) *Paracelsus, de virib. membror.* L. II. c. 7.

(c) *Ibid.* c. 10.

(d) *Epb. German.* D. 12. an. 6, 7. p. 193. &
Roland in Lexico.

(e) *Ibid.* D. 11. an. 8. App. III.

(f) p. 88. §. 27.

(g) *Ibid.* p. 29.

(h) §. 28.

(i) p. 628.

(k) p. 377. §. 3.

(l) p. 94. §. 28.

(m) p. 85. §. 6.

be readily converted into water (*n*); and that, by the infernal fire, which is the liquor alcahest of *Paracelsus*, it may be known how much of another luminary a vegetable possesses (*o*). He also calls it a dissolving liquor (*p*). All which seems to intimate, that this secret may exist in a moist liquid form, like water.

5. In another place, he uses *ignis Gehenne*, or infernal fire, as synonymous; saying expressly, by the infernal fire, which is the liquor alcahest of *Paracelsus* (*q*). And again, in another place (*r*), native sand resists both art and nature, and can by no means be resolved, except by the artificial infernal fire alone; which artificial fire converts sand to salt (*s*). If *Helmont* therefore follows *Paracelsus* in the use of this word, we may thence discover what the word alcahest is; because *Paracelsus* has wrote expressly of this infernal fire. But more of this, when we come to treat of the alcahest it self.

6. Next, *Helmont* says, it is the highest and most successful of all salts; having obtained the utmost degree of purity and subtilty possible in nature (*t*). And hence he seems to call it the *ens primum* of salts (*u*), the *sal circulatum*, and the *sal circulatum* of *Paracelsus* (*x*). And hence the *circulatum majus* (*y*), the *sal circulatum* (*z*), the *sal circulatus* (*a*), and the *sal circulatus Paracelsi* (*b*), of which he treats in his book *de renovatione & restauratione*. Could we therefore here depend upon the sincerity and fidelity of *Helmont*, we might, from these synonymous words, and the writings of *Paracelsus*, attempt to discover this wonderful menstruum.

In origin.

7. But before we enter upon the work, we must consider the origin of the alcahest; and this, we are told, is no where to be found spontaneous in nature: because, as *Helmont* says, nature has it not (*c*); and expressly asserts, that a part of earth may be homogeneously reduced to water by art; at the same time strongly denying it can ever be done by nature alone; nature having no agent capable of reducing true earth to salt and water. Nor can it be produced, except by chemistry alone; which alone hath found a clear water, that cannot be transmuted, and is reduced to the minutest particles possible in nature (*d*); tho' not by the vulgar chemistry, but by the labour of knowledge (*e*); and this as its ultimate master-piece, as he expressly declares, repeating the word, "thus at length, thus at length, I say, chemistry prepares an universal solvent, as its ultimate effort" (*f*). And again, there is not in all chemistry a more difficult process than that for preparing the alcahest; nor a more operose thing in all chemistry; it being not obtainable by reading or meditation; but by plenitude of science, doubly confirmed, is a knowledge of this operation to be acquired: whence it is very seldom given to any one (*g*). This liquor, therefore, being of a most tedious preparation, cannot be compassed by the human understanding, tho' a person is skilled in the art; unless the Most High should, by a special gift, put him in possession of

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| (u) p. 119. §. 89. | (v) p. 380. §. 24. | (w) p. 419. |
| (o) p. 265. §. 11. | (x) p. 43. §. 11. p. 374. §. 49. | (y) Ibid. |
| p. 628, 701. §. 23. | (z) p. 576. | (a) p. 628. |
| §. 10. p. 714. §. 27. | (b) p. 700. §. 23. | (c) p. 16. §. 12. |
| (p) p. 88. §. 29. | (d) p. 94. §. 27, 28. | (e) Ibid. p. 700. §. 23. |
| (r) p. 45. §. 15. | (f) p. 387. §. 65. | (g) p. 700. §. 23. |

of it; as chosen for the purpose, by a particular privilege, to enjoy it (*f*): God alone being the dispenser of it, for reasons known to the adept (*g*). From the origin of the alcahest, here delivered by the author, it is plain how weakly they err, who fancy they can make it with ease: such pretenders at once betray their ignorance, and falsify their own tumid pretensions. Nor let them think to screen themselves, by pretending there are many alcahests: for *Helmont* flatly contradicts them, by affirming, that as, in all nature, there is only one fire; so likewise there is but one only liquor which dissolves all solids into their first matter, without suffering any change itself, or diminution of its virtues; as the adepts well know, and attest (*h*). And by means of this doctrine it is, that I have, with safety to my self, been able to keep off numerous pretenders to science; sanguine in hopes, and abounding in promises, but often proving deceitful, faithless impostors: for, after asking them a question or two, I soon found, by their answers, how little they understood of the subject they so varnished over with words.

8. Let us next consider the stupendous effects ascribed to this wonderful secret. And first, as a menstruum, it is said to exert an effectual power in dissolving all the known sensible bodies, of what kind soever; even gold and mercury, upon which no other substance can intimately act. For thus says *Helmont*: "Our mechanical art has shewn me, that every substance, as stones, flint, sand, gems, marcasite, clay, earth, brick, glass, lime, sulphur, &c. may be transmuted into an actual salt, equal in weight to the body which affords it: and I know how to reduce plants, flesh, fish, bone, and every thing of the like kind, into their three pure principles. But metals, on account of the equal commixture of their seed, are very difficulty reduced to salt; so likewise is sand (*i*): for sand, or original earth, resists both nature and art; and will not quit its primitive constancy, by the power of either: and it is only by means of the artificial, infernal fire, that sand turns to salt, and at length to water (*k*). Again, the alcahest of *Paracelsus* transmutes all the natural bodies, by subtilizing them (*l*). And elsewhere, all bodies are easily reduced to water, by means of *Paracelsus's* liquor alcahest; even such as otherwise cannot be resolved into their three principles (*m*): and, by its means, all vegetables, even charcoal made of oak, are changed into a liquor, that leaves no scæces behind, upon distillation (*n*): for one and the same liquor alcahest, perfectly reduces all the tangible bodies of the whole universe, into their original life (*o*). And thus it likewise acts upon all poisons (*p*). It dissolves all things, except itself, as hot water dissolves snow (*q*): even oil, and spirit of wine (*r*); cedar-wood (*s*); all the kinds of *elixir proprietatis* (*t*); the *ludus* of *Paracelsus* (*u*); mercury (*x*); and even gold itself (*y*), which cannot otherwise be radically reduced into its component principles, by any solvent whatever; as it is much easier to make gold than to destroy it, according to the unanimous consent of philosophers."

g. Let

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| (<i>f</i>) p. 714. §. 27. | (<i>g</i>) p. 704. §. 2. | (<i>q</i>) p. 380. §. 24. | p. 387. §. 65. |
| (<i>h</i>) p. 677, 678. §. 6. | (<i>i</i>) p. 4. §. 11. | (<i>r</i>) p. 576. | (<i>t</i>) p. 634. |
| (<i>k</i>) p. 45. §. 15. | (<i>l</i>) p. 55. §. 7. | (<i>u</i>) p. 700. | (<i>x</i>) p. 776. §. 11. |
| (<i>m</i>) p. 85. §. 6. | (<i>n</i>) p. 88. §. 27, 29. | (<i>y</i>) p. 706. §. 10. | |
| (<i>o</i>) p. 265. §. 11. | (<i>p</i>) p. 374. §. 49. | | |

*Its manner of
acting.*

8. Let us next consider the manner wherein the alcahest exerts its efficacy upon the subjects. Its power, we find, is always increased by fire; tho' only a small degree thereof is required in digesting, distilling, or cohobating: for, a coal of oak and the alcahest being put together, in equal quantities, and the containing glass *Hermetically* sealed; the solution was performed in three days time, by digesting in a bath-heat (z). The *sal circulatum* by bare digestion, wonderfully changes all oil, and spirit of wine (a). The alcahest being put to an equal weight of cedar-wood, reduced to chips; and the glass *Hermetically* sealed; the whole substance of the wood was, with a warm digestion, for a week, changed to a milky liquor (b). Sometimes, also, the business is performed by a single distillation; for, the liquor alcahest being once distilled from common mercury, leaves it behind, coagulated and reducible to powder; but neither increases nor diminishes its weight: and this it does in a quarter of an hour (c). But in other cases, cohobation is required before the desired effect can be obtained; for, bodies turned into salt of equal weight respectively, are sometimes to be cohobated with the *sal circulatum* of *Paracelsus*, before they dispossit all their fixity (d): especially metals, and principally gold, by reason of the perfectly equable commixture of their seed (e). But otherwise, a single distillation of the alcahest, from the *ludus* or *cevilla* of *Paracelsus*; being a stone found at the bottom of the *Scheld* near *Antwerp*; will in two hours convert the whole stone into salt of the same weight. Nor, do I find any other way of applying this universal solvent; nor, that a greater force of fire is required: it may therefore dissolve all bodies, by means of a gentle agitation of its own parts, occasioned by fire; for the alcahest may be distilled with the second degree of heat of a sand-furnace (f); and does not rise with the tepid warmth of a bath (g).

Its effects.

9. There has been nothing in all nature, hitherto observed or related, more surprising than the physical change which these authors attribute to the action of this menstruum; as it at once changes the whole body of the subject into a different mass, without the least alteration of weight in the operation. The mass, after being thus changed, seems always to appear either in a fluid or saline form, tho' with some difference; for quick-silver, by the action of the alcahest, becomes a fixed powder, that may be ground, and resists a blast-heat, and the power of lead upon the test (h). And almost all other bodies are by it turned into an equal weight of salt (i). Oak charcoal is immediately changed by it, into two transparent liquors, different in colour and gravity (k). Cedar-wood is changed into a milky liquor, of the same weight, and afterwards into two kinds of oil, which by bare digestion turned to a pure salt, miscible with water (l). The *ludus* of *Paracelsus*, in two hours time, by a single gentle distillation, is totally converted into a salt of equal weight, which runs *per deliquium* in the air, and affords a fluid without any fæces (m). From all which it is plain that this solution, tho' it differs

at

(z) p. 88. §. 29.

(a) p. 567.

(b) p. 776. §. 10, 11. (i) p. 43. §. 11. §. 15.

(h) p. 634.

(c) p. 628, 776.

p. 56. §. 12.

(k) p. 88. §. 29.

(d) p. 43. §. 11.

(e) Ibid.

(l) p. 634.

(m) p. 700. §. 23.

(f) p. 88. §. 29. (g) p. 88. §. 29. & p. 634.

at the first, yet at length always reduces the dissolved bodies to the form of a salt, soluble in water, except quicksilver; which, on account of its great purity and simplicity, cannot be turned into salt: whence, it radically resists all the possible separations of art or nature, and therefore, is perfectly indestructible (*n*). These bodies, therefore, when turned to an equal quantity of salt by the alcahest, still retain their peculiar virtues depending upon their seminal powers; which consequently are peculiar and incommunicable. This remarkable property is described, where he says (*o*) That 'the alcahest of Paracelsus transmutes all the bodies in nature, by subtilizing them: for, when bodies are subtilized as high as possible, they at length change to another substance, but retain their seminal properties (*p*): and by means of the universal solvent all things are brought back to their *Ens primum*, and retain their native virtues; whence great and unlimited powers may be obtained.' And plainer still (*q*); 'This liquor only, can dissolve all solids into their first matter, without any diminution or alteration in itself.' Whence he recommends 'the knowledge of that homogeneous and immutable menstruum, which dissolves its subjects into their first liquid matter; whereby the internal essences of things, and their properties, may be seen (*r*).'

10. By this means, therefore, all these bodies turn to a saline, volatile substance, containing the presiding spirit of each subject, respectively; which saline matter may be intimately mixed with all the animal fluids, and circulate with them thro' all the vessels thereof, so as every where in its passage to exert its peculiar virtues upon the body. Whence, such substances have been called potable; and thus, for example, by potable gold, the adepts understood gold reduced to such a saline body; tho' they have only boasted themselves possessed thereof, either thro' vain-glory, or the spirit of delusion. Gold dissolved by acids, is no more than a liquor containing unaltered particles of that metal; but the *aurum potabile* of the philosophers, is of equal weight with the gold employed, without the admixture of any menstruum, and, only the pure, first matter, or *ens primum* of the gold itself (*s*).

11. The most extraordinary thing belonging to the alcahest, is its being capable of dissolving bodies, without mixing itself among them; but, remaining perfectly separate from all their particles, without increasing or diminishing the weight of the substance dissolved; as plainly appears (*t*) hence, that oak-coal was, with a bath-hear, dissolved by it into two distinct liquors of different colours and properties, and thus came over by distillation, leaving the solvent liquor behind, of the same weight as at first: for, he found no body, whereto the alcahest would unite; being itself a pure, subtile substance, reduced to the smallest possible particles; and, therefore incapable of all fermentation and admixture (*u*); so that it produces its effect by a bare external action, and not concreting with the body it changes: as, the purest fire acts upon its objects; or, as hot water dissolves ice (*x*). For this liquor leaves no part of itself mix'd with the body dissolved (*y*).

61.

(*n*) p. 55. §. 8. p. 705. §. 10. (*o*) p. 55. §. 7.
(*p*) p. 387. §. 65. (*q*) p. 667, 678. §. 6.
(*r*) p. 780. §. 25.

(*s*) See Helmont, p. 700. §. 20 (*t*) p. 88. §. 28.
(*u*) p. 94. §. 27, 28. (*x*) p. 380. §. 24 p.
677, 678. §. 6. (*y*) p. 776. §. 10, 11.

12. Hence, the alcahest appears to have two extraordinary properties, with respect to all other menstrums; *viz.* (1.) That it does not act by attraction, or repulsion, but entirely by a certain mechanical force; contrary to all other of the known menstrums, unless perhaps, we except fire. (2.) That it constantly preserves all the native virtues of the bodies it dissolves; and yet, when it resolves poisons it deprives them of their virulence, or noxious quality, and endows them with the highest medicinal virtues, by reducing them into their first matter (*z*); which is extremely difficult to understand.

13. When the alcahest has thus reduced all bodies into their saline and volatile *ens primum*, so as to retain their respective native virtues; if the subjects be farther urged, by the action of the same solvent, they lose their saline nature, and all their proper seminal virtue: whence, all these different subjects are reduced to the same indolent, scentless, insipid, simple, elementary water: so that, by applying this solvent too long, the former excellent productions are destroyed. From hence, at the same time, it appears that water must thus be the ultimate manner of all tangible bodies; the alcahest itself being unable to act any farther upon this water: which, however, being again impregnated with what seed soever, may thus pass into any new kind of body.

14. The author expresses himself thus: 'All bodies, we see, are transfutable into an actual salt, equal in weight to the original subject; which salt being several times cohobated with the *sal circulatum* of Paracelsus, loses all its fixedness, and transmutes into a liquor, which at length becomes insipid water, equi-ponderant to the salt that afforded it (*a*). Native sand turns to salt, and at length to water, by means of the artificial, infernal fire, and by no other (*b*). I know a water, by means whereof all vegetables are changed into a distillable liquor, without leaving any scæces at the bottom of the glass; and this distilled liquor is totally reduced, with alkalies, into insipid, elementary water (*c*). Oak-coal converted into two liquors by the alcahest, rises by distillation, with the admixture of a little chalk, nearly of its original weight; and has all the properties of rain-water (*d*): and, thus all things become so volatile, as to rise with a bath-heat; leaving the alcahest behind at the bottom (*e*).

Its immutability.

15. It appears extremely strange, that this menstruum, which has such wonderful effects upon all sorts of bodies, should never be in the least diminished, altered, or impaired by them: in which respect, it truly resembles fire; whereto it may, therefore, justly be compared. Thus the author clearly says, that, it acts upon all sublunary bodies, without being acted upon (*f*). And when it had so wonderfully dissolved the oak-coal, it remained at the bottom, still of the same weight and virtue (*g*). Accordingly, no transmutation of the alcahest is to be expected; because there is no other body it can join or ferment with: whence, it never dies (*h*). With its utmost action, therefore, it reduces all tangible bodies into a middle life; without suffering any change, or diminution of its virtues (*i*). It is, therefore, immutable

(*z*) p. 374. §. 49. (*a*) p. 43. §. 11.

§. 24. 634.

(*f*) p. 45. §. 15.

(*b*) p. 45. §. 15. (*c*) p. 88. §. 27.

(*g*) p. 88. §. 29.

(*h*) p. 54. §. 27, 28.

(*d*) p. 88. §. 29. (*e*) p. 88. §. 29. p. 380.

(*i*) p. 265. §. 11.

table and immortal (*k*). It is the only substance not altered by action (*l*). It acts, therefore, without suffering re-action, or being itself weakened (*m*). For, it is an homogeneous, and immutable dissolvent (*n*). And remains numerically the same in weight and virtue; as well after being a thousand times employed, as after being but once used (*o*).

16. It is farther to be observed of this menstruum, that it has a wonderful degree of fixedness, or volatility, in the fire: for, after it has rendered all bodies, even those of the most fixed kind, so volatile as that they may be distilled over with a bath-heat; yet itself does not rise with them, but remains fixed at the bottom (*p*). At the same time, the alcahest is so volatile, as with the second degree of heat in a sand-furnace, to rise by distillation, along with the bodies it had dissolved (*q*). Whence, it may be drawn off from common mercury, thus fixed, and coagulated (*r*). And from hence, we have the exact limitation of the small degree of heat, wherein the full power of the alcahest is exerted upon all the bodies in nature. *Its volatility.*

17. We must farther observe, that tho' the alcahest be inseparable by all other bodies, and ought never to be impaired; yet there is one substance in nature, wherewith it may unite. This plainly appears from considering the following passage of the author (*s*). 'Chemistry is anxious to find a body of so great purity, as not to be dissipated or corrupted; and at length the art was astonished upon discovering an aqueous liquor, which being reduced to the minutest atoms possible in nature, would not unite with any ferment; whence, its transmutation was despaired of, as not finding a body more noble than itself, wherewith to join: but, the labour of philosophy made an anomalous thing in nature, which without mixing with any ferment, rose different from itself. This serpent biting itself, recovered from the poison; and was, thence, immortal.' *Its equal.*

18. Whence, we see, that here was a certain conjunction of two things, however different they might be. This appears more plainly, and distinctly (*t*) where he says, that one and the same liquor alcahest, perfectly reduces all the tangible bodies of the universe, into their first life, without suffering any change itself, or loss of virtue; being only subdued and changed by its equal. In another place he comes nearer to the point (*u*), where he says, that, mercury freed from its original sulphur cleaving to its innermost part, is immutable in the fire, and immediately consumes all other feeds, except its equal.

19. Thus, I have given a faithful account of the alcahest, upon the credit of *Helmont*; and do not remember, that I have any where else read of such a thing; which is not spoke of by the ancient philosophers, physicians, or other chemists, tho' it be the most desirable particular in all physics. It will, therefore, be expected I should say somewhat of the matter it is to be made from. And, I must own that I have tried an incredible variety of experiments to this purpose; and have sometimes repented of and detested the labour. *Its matter.*

E e e e

20.

(*k*) p. 377. §. 3. (*l*) p. 380. §. 24. p. §. 27, 29. p. 634, 703, 776 §. 10.
628, 634, 677, 678. §. 6. (*m*) p. 704. §. 27. p. (*q*) p. 88. §. 29. (*r*) p. 776, 628.
776. §. 10, 11. (*n*) p. 780. §. 25. (*s*) p. 94. §. 27, 28. (*t*) p. 265. §. 11.
(*o*) p. 776. (*p*) p. 56. §. 14. p. 88. (*u*) p. 56, 57. §. 24—17.

The circula-
tum minus.

20. Paracelsus had a liquor procured, by a most tedious process of circulation, from sea-salt, wherein nature has placed the utmost perfection. This salt he, by incredible industry, reduced to a perpetual oil, and calls it the *Ens primum* of salts: the oil of salt, the liquor of salt, the water of salt, the lesser *sal circulatum*, and the less *circulatum* (*w*). The preparation of the *sal circulatum* is troublesome, tho' clearly described; excepting that one cannot say what kind of spirit of wine is here directed, to separate the impure from the pure. This preparation perfectly corresponds with what *Helmont* says; viz. that 'the salts of bodies, several times cohobated with the *sal circulatum* of Paracelsus, turn to water (*x*).² And, hence, he ascribes the virtues of the alcahest to the *Ens primum* of salts (*y*). He farther declares that all poisons are destroyed by the *sal circulatum* (*z*). Hence, he calls it the highest and most successful of all salts; which being brought to the utmost degree of purity, and subtilty, pervades all bodies, and readily dissolves them; itself remaining unchanged in the action (*a*). This *sal circulatum* has a wonderful effect upon oil and spirit of wine (*b*); and reduces bodies into the liquor whereof they were concreted (*c*). He also says, that the *ludus* may be prepared with it (*d*).

The circula-
tum majus.

21. But, Paracelsus had another solvent, much more powerful, and much more difficult to be obtained, than the *circulatum minus*; whence he has called it the *circulatum majus* (*e*). He appositely terms it the matter of mercurial salt: and thence, likewise calls it the living fire (*f*). Now, he acknowledges that the highest fire, and celestial life, lie hid in common mercury: and says, the quintessence of mercury is celestial fire, if dissolved with its parent, or the secret of salt (*g*). When, therefore, these two are intimately combined by a true union, and brought to a high degree of purity, subtilty, and volatility, they seem to make that wonderful mercurial water, which he describes in his chapter of the specific solvent; where, he says, 'that gold dies therein, so as no longer to remain gold: whereas, in other solutions of that metal, it is only minutely divided, and still remains true gold; being always easily recoverable, in its pristine form, upon redaction.' By this means, therefore, there is a perfect union made of water with water: for, here are two kinds of water employed; viz. the common water contained in the salt, and the metallic water contained in the mercury, tho' they both are supposed to have the same origin.

Mercury and
salt recom-
mended.

22. All this seems to have been understood in our sense by *Helmont*; as appears by the following passage (*h*). 'The internal mercury of metals, purified from all its metallic sulphur, remains every way undissolvably united; so as radically to suffer no division, either by nature or art. Nor, should I ever have learnt the nature of water, had it not been for the correction of *Mercury's wand*; whereby I find the nature of mercury adequate to that of water: for mercury contains no earth; but is constantly produced by water (*i*).'³

Again,

(w) Lib. IX. Archid. in remedio ad maculas. In tractatu de sale, c. 4. In correctione & additione. L. de Renovat. Archidox. IV. c. 4. Essentia de salibus. Archid. L. VIII. C. de elixire salis. Quintæ essentiz extractio de salibus. Archidox. X. c. 2.

(x) p. 43. §. 21. (y) p. 419.

(z) p. 374. §. 49. (a) p. 380. §. 24.

(b) p. 576. (c) p. 628.

(d) p. 700. §. 23. (e) Archidox. X. c. 4.

(f) Archidox. X. c. 5, 6.

(g) Archidox. X. c. 17.

(h) p. 55. §. 8. (i) p. 56, 705. §. 10.

Again, ' if I had not, with all the ancient alchemists, seen that quicksilver eluded all the skill of artists; so as either totally to evaporate in the fire, or totally to resist the utmost violence thereof; and in both cases, remain unchanged, or identically the same primitive, homogeneous substance, I should say that the art was false; which, on the contrary, I find to be true: so that, what is above, resembles what is below; and, *vice versa*. And, hence, it is perfectly impossible, either by art or nature, to find a diversity of parts in the homogeneous substance of mercury; even the alcahest itself cannot do it: for mercury is more simple than gold, and more identically, and more equably composed: whence, mercury is nearly as indestructible as the elements themselves; so that all sublunary things are too weak to subdue, penetrate, change, or contaminate pure mercury; which remains untouched in the air, in fire, and in corrosive liquors: for it is not touched, much less penetrated by any dissolvent; and, therefore, there is nothing in nature, like to this pure mercury, by many degrees (*k*). It is hence like, and nearly approaches to the *Ens primum* of metals (*l*). And exists actually simple, and not as a constituent part of bodies (*m*). And for all these reasons, we know that it only can be subdued and changed by its equal alone (*n*). Because this anomalous production in nature, rises without any different ferment mixing with it; but biting itself, it recovers from the poison, and afterwards proves immortal (*o*).

23. And, this is all the history I can give of the alcahest of *Paracelsus*, and *Helmont*, faithfully extracted from their own writings: whence, it is easy to see, that this menstruum is not to be sought for in human urine, or any productions thereof; nor, in tartar, or any of its preparations: though a substitute may hence be had for the principal (*p*). Nor can phosphorus be ever employed for this purpose; as being repugnant to the properties above laid down. *Glauber* was mistaken, when he sought the alcahest in the fixed alcali of nitre: and, *Zwelfer*, when he sought it in the strong spirit of vinegar, distilled from verdigrease. *Rosfinkius* had no just notion of the thing, when he supposed it to consist of the fixed alcali of tartar for its basis, joined to an acid of the mineral, vegetable, or animal tribe: for, salt of tartar with the vinegar of antimony, makes only the tartar of vitriol; with vinegar, from wine, a *tartarus tartarificatus*; and, with acid whey, only a better sort of the same: nor does the addition of sal-ammoniac much alter the matter (*q*). But, no one seems to have better understood the meaning of *Paracelsus* and *Helmont*, in describing the alcahest, than *Petrus Johannes Faber*, in his manuscript upon alchemy, sent to the duke of *Holsace*, and published in the *German Ephemerides* (*r*): where there is a remarkable confirmation of my opinion, to the following purpose. The liquor alcahest is a pure mercurial, metallic spirit, so closely connected to its own natural body, that these two become one inseparable, indestructible substance, destroying all things, and turning them into their first matter. It is a true philosophical mercury, chosen from the mineral kingdom, and joined with its

E e e e 2

own

(*k*) p. 670. §. 17. (*l*) p. 705. §. 4.

(*m*) p. 670. §. 17. (*n*) p. 265. §. 11.

(*o*) p. 94. §. 28. (*p*) p. 780. §. 25, 26.

(*q*) See *Eph. Germ. D. 1. Anno 6, 7. p. 193.*

— 196. *App.*

(*r*) *Ephem. Germ. D. 11. Anno 8. App. p.*

own pure body; whereby it becomes an inseparable, milky, butyraceous liquor; which penetrates and dissolves all things: it is of two kinds, simple, and compound; the simple is made of a pure metallic acid, and a pure metallic salt, rendered volatile with its own spirit. It is very difficult to prepare: but the compound sort is, still, much more difficult; being made of a mineral acid, and the pure saline matter of animals and vegetables. The liquor alcahest, or the pure, philosophical mercury, is an incorruptible, and unalterable fire of nature, that reduces all things into their first matter. The industrious *Becher* is nearly of the same opinion, where, in his book *de subterraneis*, he says, he discovered in sea-salt, a certain arsenical, and mercurifying power; which, when separated pure, would be the alcahest; tho' a very different thing from the philosophical mercury: and, hence, he takes mercury, for a sulphureous metallic substance, which of itself would be solid; but that, it receives all its fluidity from the arsenical sulphur of common salt. This is a subtle insinuation; and I wish he had given it fuller. His argument runs thus: the purest quicksilver being dissolved in spirit of nitre, and precipitated with spirit of sea-salt, becomes volatile, and disposed to part with its mercury easily; consequently, sea-salt may convert the purest metals from their own fixed nature, into true mercury.

24. It may here be expected I should declare my sentiments, whether any chemist was ever in possession of the alcahest. I answer frankly, that *Helmont* complains the phial of it, once given to him, was taken from him; whence it is certain, he could not have made many experiments with that liquor: and as for *Paracelsus*, he does not deliver so many, and such remarkable particulars of his own solvents; so that, I know not what to say upon the whole matter. Thus much I can truly say, that if any one will treat sea-salt, and mercury, in every chemical way (which I would advise to be done) he will have no cause to repent of his labour.

Of the CHEMICAL APPARATUS and VESSELS.

Vessels, what. 1.

Instruments,
what.

The furniture
of a labora-
tory.

AS the whole of chemistry is employed in producing and observing the changes of bodies; and, as these changes are principally brought about by the application of fire; hence, in the practice of the art, there is an absolute necessity of using proper instruments and vessels; without which, no operation could be performed. By vessels, I understand all those hollow bodies wherein any subject to be chemically changed, or already changed, as also the changing substance itself, or solvent, is contained. And by the name of instruments, I understand all those bodies, which have such a firmness, size, and figure, as render them fit to apply the changing causes to the subjects, so as thereby to excite a determinate motion, according to the rules of the art; and, at the same time, enable the operator to manage and regulate these causes, as well as the subjects to be altered. And, indeed, the whole chemical apparatus consists of bodies changed by art, of changing causes, of vessels, instruments and chemical productions, in order to furnish a laboratory properly.

2. The vessels employed in chemistry should be capable not only of containing the subject to be changed, but also of sustaining or resisting the acting causes, and the fire applied, so as not to fail whilst the operation is in hand: whence, consequently, these vessels should be strong, and not subject to be fouled or damaged: and such we may call containing vessels. The other sort, which receive the bodies already changed by the action of the proper causes, being almost constantly separated from the subject, by means of fire acting upon it through the containing vessel, may be called by the name of receiving vessels. *Requisites in the vessels.*

3. In both these kind of vessels, we are chiefly to regard their matter, and their figure. As to their matter, it is either of wood, glass, metal, or earthen-ware. The wooden vessels, made of dry wood, not abounding with oil, and not painted or varnished, are esteemed the best for preserving salts, or saline bodies, or bodies that have been calcined; provided the vessels are dry, and kept close covered: for thus such substances may be well preserved, which, in all other vessels are apt to relent with the moisture of the air. And mortars, or dishes made of turned wood, are properly used for grinding and washing the amalgams of metals with water; for which purpose they are preferable to all others: and, being rubbed on their inside with chalk, they are useful in reducing melted lead, and tin, to powder; but we seldom use them for other purposes. *Their matter. Of wood.*

4. Glass-vessels are excellent; as neither changing, adding, or taking from the bodies they contain; and sustaining the fire, without suffering any thing to enter, or get out at their pores, except fire, and the magnetical virtue; so that they retain even the alcahest itself in digestion. And hence, in every chemical operation and experiment, glass-vessels are constantly to be used, where no greater heat is required, than glass can sustain without melting. And as the green German glass soils bodies the least, is the strongest, and bears fire the longest without melting, such glass should be preferred before any other kind; especially before the white crystalline glass, which easily cracks, melts, or lets go its alkali, whereby it might communicate that alkali to the subject: whereas the strong green glass sustains above six hundred degrees of fire without melting; though I have brought it to melt in the strongest heat of a sand-furnace. Whence I wish that *Helmont* had discovered his coating, which, he says, would prevent glass from melting in the strongest naked fire of a wind-furnace; so that he could distil highly-rectified oil of vitriol in a glass-vessel; while this coating neither crack'd, fell off from the vessel, nor vitrified too much; for thus, he asserts that the glass was cemented internally with the coating, in the utmost violence of fire (a). If we had this secret, almost all the chemical operations might be performed in glass; but I am neither acquainted with any such coating, nor have found any person that was. *Of glass.*

5. Of all the metals, iron is the hardest to melt; whence many chemical vessels are made of iron. But all metallic vessels have these two defects; that they are corroded by ignited salts, which are hence either rendered impure or lost; and *Of metal.*

(a) See *Helmont*, p. 707. §. 19.

and that they melt in a strong fire. I directed iron-retorts to be made of cast iron, in order to distil the phosphorus of urine; but found they melted in the fire, long before the phosphorus would come over.

Of earth.

6. Upon account of these defects in iron-vessels, others have been formed of different earths, for chemical uses; but these also, when made of fat clay-like earth, vitrify in a violent fire, and fail in the operation. The best pottery, for the purpose, is that made of a more dry and hungry earth, as the *Hessian*, and the matter whereof crucibles are formed, which resist a violent fire: but, being porous, they suffer saline matters to transude, especially when acid spirits are distilled in them. From hence we may see, what kind of vessels are required for every operation respectively. Thus pure aqueous liquors, and perfect spirits, produced by fermentation, may be distilled in metallic vessels; whilst vegetable spirits, of the acetous kind, may be distilled in vessels of pewter, or such as are tinned: but other saline liquors require vessels of glass. Worms, used in the distillation of acid liquors, are made of tin; but the still-heads, for the reasons above-mentioned, are always best made of glass. Earthen vessels are only necessary, where the utmost force of fire is required; and then, to prevent exudation and cracking, they should always be coated with a proper luting.

Indian earthen vessels.

7. Hence, therefore, before any chemical operation is begun, we are first to consider the subject to be operated upon, and the degree of fire required in the operation, in order to determine what kind of vessel to use: but, where the choice is free, we should always make use of a glass, on account of observing the appearances and changes which happen to the subject in the process; which, besides the pleasure of it, has great uses both in chemistry and natural philosophy: as thus we may see the cause of numerous phenomena. There is also a grey kind of potters-clay, that comes from the *East-Indies*, appearing like porcellane, and being perhaps a species thereof. It is there made into both large and small vessels, in order to preserve their commodities, and export them safely. These *Indian* vessels are not dissolved or corroded by acids; and are therefore often used by the makers of *aqua-fortis*, as proper receivers for acid spirits.

The figures of vessels for holding the preparations.

See plate IX. fig. 3.

Vessels for operations.

8. All vessels, of whatever matter they consist, may have a great variety of figures; the principal whereof, for chemical purposes, are the following. The glass-vessels which I best like for preserving volatile liquors and salts, are such as have a cylindrical form, with a flat internal bottom, and a narrower cylindrical neck, that may be exactly closed with a glass-stopper; which the more surface it has the better, so as to come in contact with the whole internal surface of the neck. The small glasses, out of which liquors are to be dropped, may be bellied, and have a cylindrical neck, widening, and somewhat hollowing at the top. They may be stopped with a cork; or with wax, if they contain volatile acid spirits.

9. The vessels for chemical operations, and especially for distillation, must be of different figures, according to the end proposed to be answered: and only two kinds of vessels are here required, one to contain the body to be changed, and to which the fire is applied; the other to receive the parts separated from the

Fig. 4. p. 583.



ible & melting Nibels



ing Neck to be placed
etc.

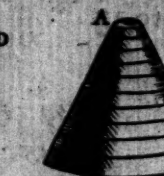
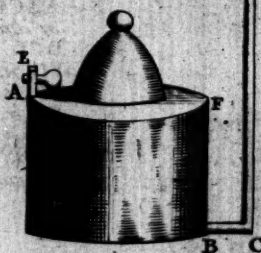
J. H. G. G. G. G.

Plate IX.

Fig. 1.

p. 443.

AB. A brass Cylinder.
B. An Aperture into the Tube.
E. The Cock fixt just above the part AF.

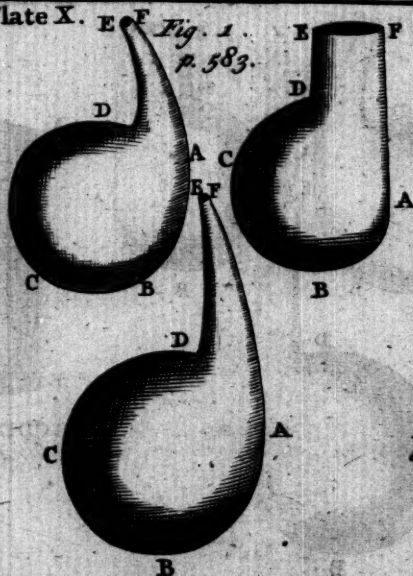


AB. A steel Cone.
CD. A hollow n.

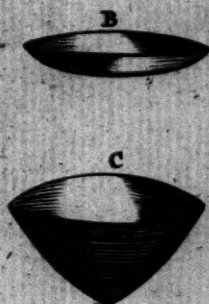
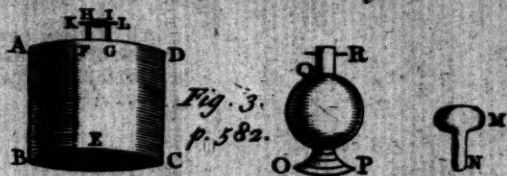
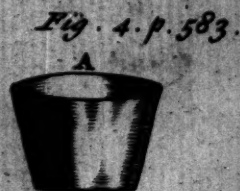


ABC
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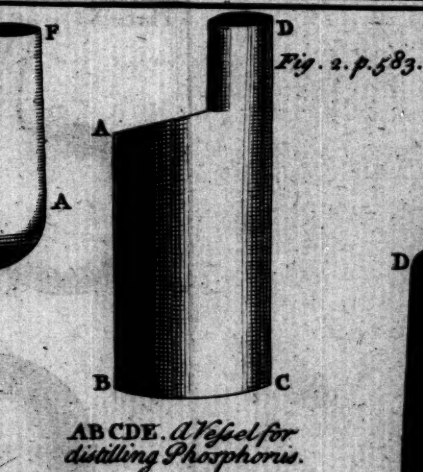
Plate X. Fig. 1. p. 583.



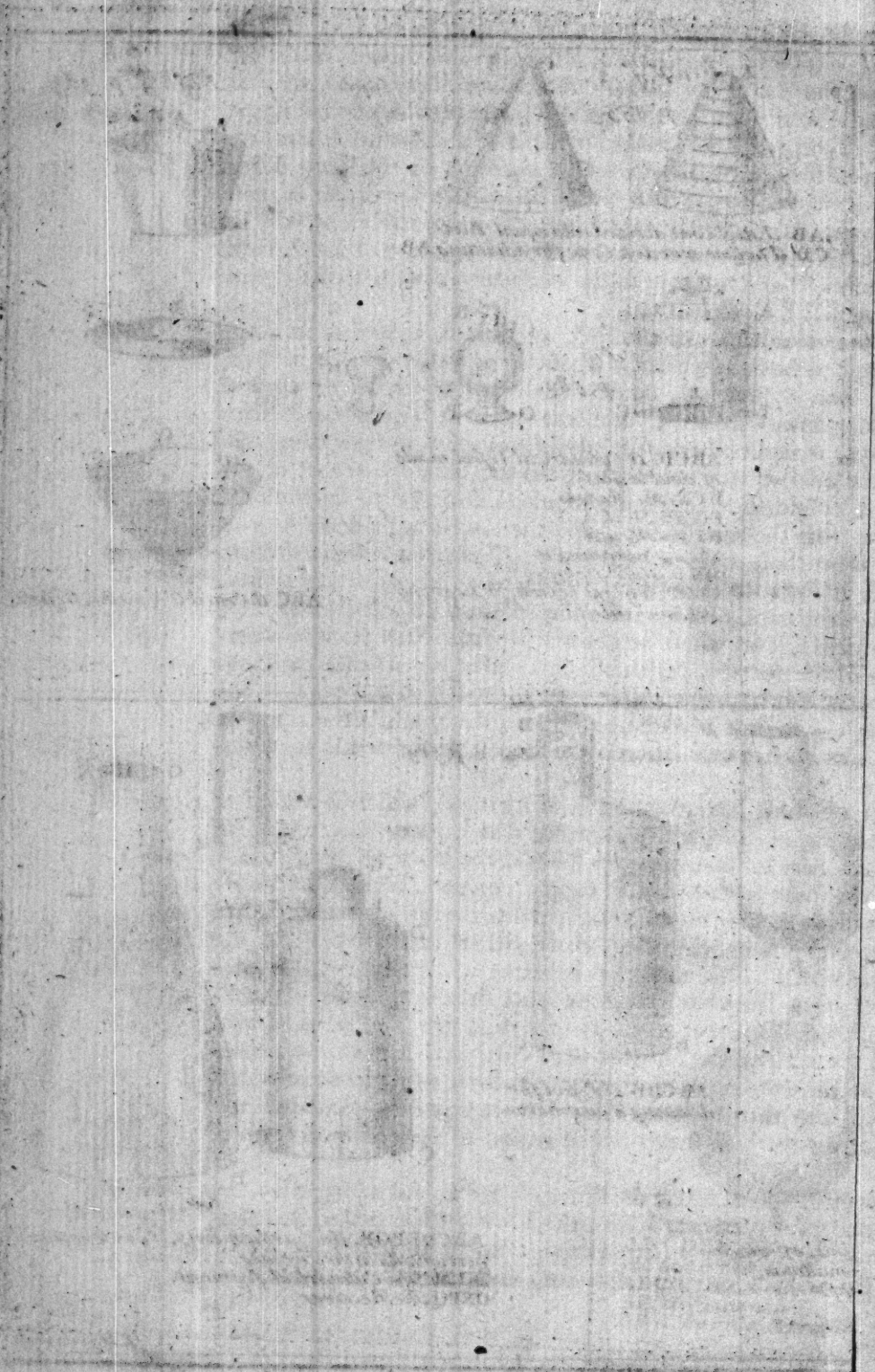
ABCDEF. Three Retorts, of which
the last is the most commodious.
ABCD. The Belly thereof.
AF. A Tangent to A.
DE. A Parallel to the Tangent AF.



ABC. A Crucible & melting Vessel.



ABCDEFGH. An Earthen long Neck to be plac'd horizontally in the Furnace.
IJKL. The Cylindrical Segment.
ONPQ. The Receiver.



the subject by the fire, and which is always design'd to be cooler. When only the fixed part of a subject is required, after the separation is made by the fire, the figure of the vessel is commonly that of an obtuse conoid, with its base at the top, and obtuse apex at the bottom; whence this conical figure may be varied till it comes to the hollow segment of a sphere. Thus crucibles and melting-pots resemble cones; whilst roasting or calcining dishes resemble hollow segments of a sphere. It is a rule for the figure of these vessels, that the lower and wider they are made, the more easily the volatile matter flies from the fixed; and that the fire is applied to more of the surface, both of the whole subject and its fixed part: whence we always make choice of low and wide vessels for calcination.

10. But when the volatile part of a subject is required, as well as its fixed part, and both must to be had separate, the containing vessel may be of three different figures; *viz.* cylindrical, conical widening upwards, or conical again, but widening downwards. Cylindrical vessels only keep bodies from flying off side-ways, without otherwise hindering or assisting their rising upwards; whence the only variety here arises from the different height of the sides. The tallest cylindrical vessels are required in order to separate the most volatile parts from the less volatile; and the lowest to separate such as are almost fixed, from those that are quite fixed. But when vessels rise from a narrow bottom, and gradually widen upwards, as in hemispherical dishes, it is plain from hydrostatics, that all the points of the hollow basis would sustain a little column of liquor, whose height reaches from each point to a corresponding point of the surface, perpendicularly over it; whence these columns are always the shorter, the nearer they approach to the edge of the vessel, and *vice-versa*; so that a widening figure greatly assists the rising of volatile particles: and hence exhalation is the soonest performed in such vessels.

11. And hence we may have the notion of a retort; which is a kind of hollow sphere, ending in a cylindrical neck, whose upper horizontal line is a tangent of the sphere in its upper apex; whilst the lower line of the neck is a diameter of the same sphere, parallel to that tangent: whence such a retort easily determines the rising volatile particles into the cylindrical neck, and thence into the receiver; after being somewhat confined and beat back by the arched part of the vessel. And this kind of retort is adapted to the separation of very fixed parts, from those that are quite fixed; as we see in the distillation of oil of vitriol, spirit of nitre, spirit of salt, &c. The glass-men commonly bend the neck of the retort downwards, and draw it into a conical figure, open at the end; in order that the vapours, rising into the widest part of this neck, may thus spontaneously fall downwards, condense and distil into the receiver: which shews us the reason of the common form of the retort.

12. But in low distillations, where the strongest fire is, for a long time, required to raise ponderous particles, I use cylindrical vessels, placed horizontally, with their upper horizontal part opening into an horizontal neck; by means whereof the distillation of phosphorus, and other bodies which rise with

Crucibles and melting-pots.

See plate IX. fig. 4.

See plate XII. and XV.

Evaporating vessels.

Retorts.

See plate X. fig. 1. &c.

Best kind of long-necks.

See plate X. fig. 2.

See plate X.
fig. 3.

with difficulty, is commodiously performed. And when I prepare large quantities of oil of vitriol, or other fossil acids; instead of retorts, I always use cylindrical earthen bodies, or long-necks, with wide cylindrical mouths: which I find to be an advantageous way of distilling the mineral acids; for by inserting hollow cylinders into the mouths of these vessels, and applying large glass-receivers horizontally to the other ends, and luting the junctures, I thus distil with safety. And hence, I conceive, I have sufficiently given the foundation for assigning the different figures of vessels used in distillation; the rule whereof comes nearly to this, that the more difficulty any subject rises in distillation, the more it requires the figure and accommodation of the vessels last-mentioned.

Bodies or cucurbits.

See plate XII.
fig. 1.

13. But if the matter to be sublimed is so volatile as easily to rise and separate from the part to be left behind, whilst the two do not greatly differ in volatility, then vessels of a contrary figure are required. And such vessels are those conical ones, called bodies, matrasses, or cucurbits, and made in the form of *Hercules's club*. The ancient alchemists, as *Lully* and others, frequently call these vessels by the name of urinals. It is easy to understand, by the figure, that the liquor, raised by the fire in these vessels, must strike against their tapering sides, and thence the ascent be hindered, and the liquor beat back to the bottom again; so that if any thing rises difficultly, with this degree of fire, it seldom ascends high; but is rather kept low in the glass. And here also the wider the bottom is, with respect to the orifice at the top, through which the distilled liquor is to pass, the distillation will be performed more slowly; whence only the more volatile part can by this means be separated from the less volatile. The height of these vessels is also to be regarded; as the taller they are, the more difficult it is for the less volatile parts to rise.

A vessel for
distilling al-
cohol to ad-
vantage.

See plate II.
fig. 1.

14. From the consideration of these three properties, an excellent contrivance has been deduced; by means whereof a large quantity of simple or compound alcohol may be obtained, with little labour, fewel and expence. Thus, for example, if a conical tube be made of pewter, six inches wide in the base, and one inch wide in the vertex; and this tube be bent at the height of four feet, so as to make it return downwards in a cylindrical tube, with a part at the end fit to enter the orifice of a worm, fixed in its worm-tub, we shall here have a proper head for a cucurbit, charged with brandy, and set in boiling water; whereby a very strong spirit may be obtained at one operation: and upon repeating the process twice or thrice, this spirit is reducible to alcohol.

Chemical
phials.

15. And hence also we may clearly conceive the nature of a chemical phial, which is a spherical glass, with a long cylindrical neck open at the top; it is commonly called a bolt-head, and has considerable uses in chemistry, especially in performing the more subtle operations: for as the neck of this glass may be of any length, and may have its cavity in any proportion to that of the belly; hence any degree of resistance may be procured with respect to the liquor contained in the glass; so as to suffer scarce any thing at all to escape at the orifice, in a gentle digestion. And I have observed, in this kind of glass, that

Fig. 4.
p. 586.



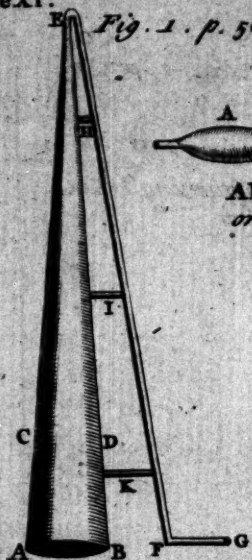
not made of
cymid.

585.

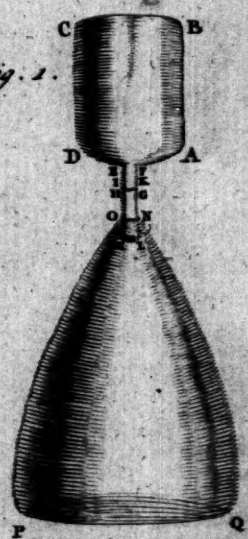


largest size

J. M. Lynde sc.



ABCD. A Tin Cylinder 6 Inches wide for distilling Alcohol, ending in a conical tube CDE 4 feet long & 1 inch wide.
 EF. A cylindrical Tube 4 Feet long & 1 inch wide.
 EG. Its Production to be inserted into a Worm.
 HIK. The Function to keep both Tubes firm.



The whole apparatus of Vessels for distilling.
 ABCDEFGH The long Neck placed horizontally in the Furnace.
 IKLM. The Tube inserted into the Mouth of that and the Receiver. ONPQ.

Fig. 2. p. 585.



Whoming Vessels.

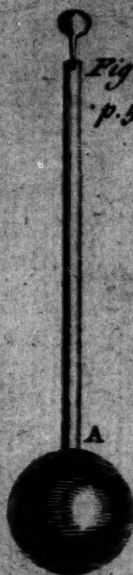
for distilling -
long k 1 inch wide at E
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Worm.
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Fig. 3. p. 586.



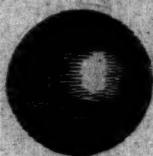
A. A Pelican.

Fig. 4.
p. 586.



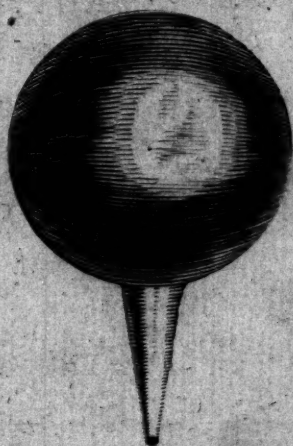
A. A Simple unit made of
2 Matryses joyn'd.

Fig. 2.
p. 584.



A. A Matryse or Bolt head

Fig. 3. p. 585.



A Receiver of the largest size

for distillation
placed hori-
the Mouth
NPQ.

J. M. ynde sc.



that the weight of the atmosphere pressing upon the hollow part of its neck, surprisngly confines the liquors and substances contained in the cavity, and agitated by the fire; thus, acting as a cork, in equilibrium to the force of the liquors endeavouring to rise; and at the same time, stopping the mouth of the bottle. For whilst the air in this glass is rarified by the heat of the fire applied, and thus endeavours to raise a proportionable column of the atmosphere, it suffers an equal resistance from the weight of that column: whence, the particles of the fluid, contained in this rarified air, are repelled to the bottom of the vessel; where, being agitated by the fire, they are more strongly applied to the subject at the bottom; as appears to the eye, when alcohol, contained in such a tall phial with a very slender neck, is carefully set over the fire: where, when the liquor nearly begins to boil, a fume is perceived to rise in the cavity of the neck, and to be driven downwards again, in the form of a fluctuating mist. By this contrivance, therefore, menstruums may be excellently digested upon their subjects, without any loss either of the solvent or solvend. And this contrivance hath enabled me to perform numerous experiments, which I could not otherways have made.

16. Thesetall phials, also, are extremely useful in separating pure volatile alkaline salts and spirits, from water, oil, and volatile earth; which might otherwise prove a difficult task. But, they are subject to one inconvenience; for, when very tall, the liquor will remain boiling hot at the bottom, or not be able to rise so high as the top, whence the upper part of the neck will remain cold, whilst the lower part thereof is strongly heated; so that, if the hot vapour rises suddenly into the cold part of the neck, the glass flies to pieces, especially in winter, or frosty weather. So likewise, if any aqueous drops are collected in the upper cold part of the neck, and fall down suddenly upon the heated parts of the glass, the vessel will burst to pieces: as I have often learnt to my cost; especially, upon digesting quicksilver in such vessels. And this may be sufficient to shew what effect the configuration of vessels will have; and the necessity there is of a particular form, to produce particular effects.

17. Receivers, especially if they be large, are of two kinds of figure; *Receivers.* being made either like bellied bottles, or cucurbits: and when their capacity may be the same, the latter should be preferred, as having its bottom at a greater distance from the orifice of the retort; whence, it affords a cooler space for the distilled liquor to condense in; as I have always found. And there is frequent occasion to increase this distance between the containing and receiving-vessel, by the interposition of cylindrical tubes, or adopters; as we mentioned above. And in the more artificial kinds of distillation, especially that of quicksilver from metals, it is necessary to use several glass adopters, to increase the distance betwixt the retort and receiver. *See plate XI. fig. 2.*

18. The retorts and receivers already described are sufficient, together *Alembic-head.* with the adopters, for performing all the kinds of distillation; except, where very volatile substances are to be separated from others, but little less volatile. And as extremely volatile substances are often required to be distilled; *See plate XV; fig. 4.* very tall and erect vessels must necessarily be employed, and cover'd with the alembic-head. Hence, it is easy to determine in what cases a cucurbit

with its alembic-head, and in what cases a retort and its receiver are to be used. But the use of the alembic-head is attended with the double inconvenience of a juncture to be luted, where it is fitted on to the cucurbit, and another where the neck of the alembic joins to the receiver: whence, as the luting is subject to crack, some part of the volatile subject may escape in the operation, whatever caution we take to prevent it.

*Circulating
vessels, or pe-
licans.*

19. There is frequent occasion in chemistry to pour back the separated volatile part upon the fixed one from whence it was raised; and this by operators is called cohobation, and by *Paracelsus*, circulation: the effects whereof are very considerable, and highly necessary. But upon observing, that by opening the vessels and pouring back the liquors in the air, a great loss was sustained; the artists, hence, invented a glass vessel, consisting of a cucurbit and alembic-head, with two tubes bending into the cucurbit again, so as directly to return the liquors rising in the head, back into the cavity of the cucurbit: and this vessel being well closed at the top, the process was thus shortened, and loss of the liquor prevented. The vessel itself they call a pelican; which is always the better, as the pipe from the top of the alembic is longer. But, as such vessels are not easily procurable, the end may be obtained by a more simple apparatus, or by using a bolt-head with a long neck, into which the neck of another less phial is inverted, and the juncture well luted, after heating the glasses, and the subject matter, sufficiently to rarify the air, and prevent its bursting the glass in the operation: tho' this contrivance is subject to an accident from the liquor cooling at the top of the glass, and falling to the bottom; which may break the glass. And so much for chemical vessels.

*See plate XI.
fig. 3, 4.*

OF LUTES.

Lutes, what.

1. **B**Y the name of lute or luting, chemists understand a mix'd, tenacious, ductile substance, which grows solid by drying; and being applied to the junctures of vessels, stops them up, so as to prevent the air from getting either in or out: but these lutings are of principal use in confining the particles raised by the fire in distillation, so as to prevent their escaping out of the vessel; whence it appears that different lutings, are required, according to the difference of the subjects to be distilled.

*Luting for
aqueous and
spirituous sub-
jects.*

2. When the subject is merely aqueous, linseed-meal ground to fine powder, and well mixed, or worked up into a stiff paste with the white of egg, makes a proper luting for the purpose: for, being applied to the junctures of distilling vessels, it grows hard with heat; and if it happens to crack, it is easily repaired by the application of fresh; which soon grows solid as before. But a paste made of the same meal, well worked up with cold water, very well answers the end in the distillation of all fermented inflammable spirits, and all volatile alkaline salts. But, this paste will not answer in the distillation of mild acids, or acetous liquors; because it softens and dissolves therewith, so as to let the fumes escape: in these cases, therefore, a bladder steeped

*For acetous
liquors.*

in

in water, till it begins to grow slimy, makes an excellent luting, by being applied and pressed wet upon the junctures of the distilling vessels.

3. A luting that acquires a stony hardness, is necessary in the distillation of the fossil acids; as those of vitriol, sea-salt, &c. which kind of luting, is called the philosophical luting; and may be prepared from the calx of copperas and quick-lime; viz. by boiling the *caput mortuum* of vitriol, in several parcels of water, till it is thoroughly washed from its saline part, then drying the powder, and preserving it in a close vessel. This powder is to be rubbed with an equal quantity of strong quick-lime, and wrought into a paste with the white of eggs, first beat thin; and this luting is immediately to be applied to the junctures of the vessels; the vessels being first a little heated. If it be not applied quick, it presently dries to a stony hardness, so as to be untractable; but, when properly used, it confines all the saline spirits, like glass itself. I prepare a luting for the same purpose, without much trouble, in this manner; viz. I beat pure sand, and potter's-clay together, in such proportion, with water, till the matter no longer sticks to the fingers; then add one fourth part of common-lime, so as to make the paste sufficiently strong: and the dryer this is applied, the better for the purpose, provided it be left ductile; for, thus it hardens into an excellent cement, the cracks whereof, if any should happen, are easily stopped up by the same. This cement is the more parable or commodious, as the best quick-lime is not often to be had.

For fossil acids, and volatile alkalies.

4. It is a great inconvenience in the stronger distillations with a naked fire, that when the vessels are violently heated, they are apt to crack, and fly to pieces upon opening the door of the furnace, and letting in the cold air, or throwing in fresh fuel; whence, it is highly proper here, to defend the vessels by a coating, from this sudden impulse of cold: and, this is frequently necessary also, when the operation is performed in glass vessels and a sand-heat, if the fire be so strong as to endanger the melting of the glass. The best luting, that I know of, for this purpose, is made by beating fat potter's-earth and powdered sand, with water, into a well-wrought paste, which will not stick to the fingers; adding thereto a little common-lime at the last, and beating them well together (*k*). Then the vessel to be coated, being warmed and exposed to the vapour of hot water, that its whole surface may become dewy, let this cement be spread all over it equably with the hand; afterwards sprinkle the surface of the coating with hot and dry sand, and set the vessel in a cool place, that the coating may dry slowly; with care to fill up the cracks in the same manner, if any should happen in the drying: and, if thus the coating be thoroughly dried, the vessel will sustain the action of a violent fire, unhurt.

Coating for vessels.

F f f f 2

Of

(*k*) There is another cement made use of by some chemists of London, to answer the same end; consisting of sifted wood-ashes, beat up to a due consistence with the white of eggs, and a little gum-water. The same service may, in a more excellent manner, be had as well for cracked glasses as broken china, or the like, from what the painters call drying oil, or a

mixture of linseed oil and ceruse, made, by insolation or decoction, into a perfectly white balsam, and afterwards ground upon a marble with fresh ceruse, till the whole is perfectly fine, and become of the consistence of an unguent. This dries slow indeed, but is very effectual.

OF FURNACES.

Several furnaces, why here omitted.

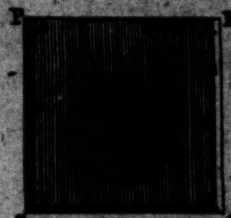
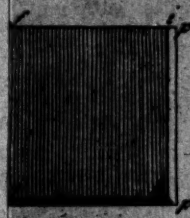
Furnaces, what.

Conditions of the best.

1. **W**E now come, in the last place, to the consideration of furnaces; but without designing to describe all those required in metallurgy, which are not necessary to our purpose. Besides, the incomparable *Agricola* hath already admirably treated this subject, in a pure *Roman* style. *Glauber* likewise describes some furnaces of a particular invention, for performing certain operations in a short manner. These authors, therefore, may be consulted occasionally; our present design being only to shew the construction of the furnaces required in our own particular course of operations.

2. By furnaces, we understand such structures as are capable of containing, restraining, and applying fire to vessels, wherein the chemical subjects are to receive the action of fire; whence every furnace requires, (1.) a fire-place, wherein the fire is to be raised, kept up, and determined. And as artificial fire must be fed by fuel, a chimney becomes necessary to discharge the smoke; as also an ash-pit, to admit the air; and lastly, a door, where the fuel is to be thrown in. (2.) In making of furnaces, care must always be taken to preserve the strength of the fire, or not to waste it in vain; and this, by directing it where it is particularly required. (3.) In building them, a proper place must also be contrived, in which the vessels, containing the subjects, may receive the requisite degree of heat, for the requisite time to finish the operation. And hence we have the conditions for building of furnaces.

3. That therefore will be the best furnace in its kind, which produces the desired effect with the least expence, interruption and inequality; and this with the greatest ease, so as not to require the constant attendance of the operator. The first condition will be satisfied, if a furnace be so built that all the heat, raised by the fire, may be applied to the subject without loss; which is obtained by making the furnace of the most solid materials, and forming its internal surface, so as to determine the force of the fire upon the place designed. Such a structure likewise will contribute, as much as possible, to ease the labour of the operator, in supplying fresh fuel. The second condition is answered, by chusing such a fuel as shall consume the slowest of any, yet afford the requisite degree of heat; and this is chiefly done by observing a proper proportion in the dimension of the fire-place, the chimney, and the air-draughts: and this proportion being duly observed, skilful operators may at once supply their furnaces with such a quantity of fuel, as will burn for a long time. The third condition is the most necessary of all; viz. that of long preserving the same degree of heat, without diminution or increase. For we know, from chemistry, that every determinate degree of fire produces a suitable, determinate effect upon every subject; whilst a greater, or a less degree, constantly alters the event: whence a great confusion must happen in chemical productions, whilst sometimes a greater, and sometimes a less



den Furnace
is 9 Inches.

high.

8 Inches high.

for supporting a Retort &c.
1 Inch wide, for the Passage
of the Furnace.

f, g, h, i. A Square hole in the upper Part of the
EDHE, into which is placed a square board that fits
into it, mark it with the same Letters.
j, k, l, m, n. The Edge of this board plan'd away to half
its Thickness, in order to be put into the hole g, h, i, which
is 9 Inches and 6 wide, when a Cucurbit is us'd.
k, l, m, n. Another square board like the former, with a round
hole o to be us'd in drilling with
a Retort.

p, q, r, s. each 6 1/2 Inches.

t, u, v. The Door of the Grate.

w, x, y, z. Four round holes in it for admitting Air to the Furnace.

1. Registers of Wood to lie therein for governing the Fire.

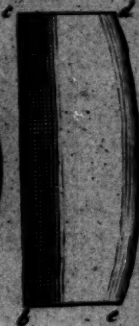
2. Da, Ca, Ec. Two folding Doors cut away in the Middle

so as when shut to leave a hole 2 1/2 Inches wide.

3. An earthen Pan us'd in the Furnace.

4. To handle.

5. To feet.



Furnace

1 1/2 Inches wide.

placed on CNOD 19

round Rim and Iron bars

1 1/2 Inches.

1 1/2 high and 6 wide.

Q, R, P, S. The Distance from the Top of the Grate 3 Inches.

R, S, T, V. The opening into the Fire Place 6 Inches wide

and 4 1/2 high.

U, K, M. The Ellipsis whose greater Axis... L, M, K, is

10 Inches.

b, c, d, e. The wooden Model us'd in its Structure.

a. A Side View of the Register.

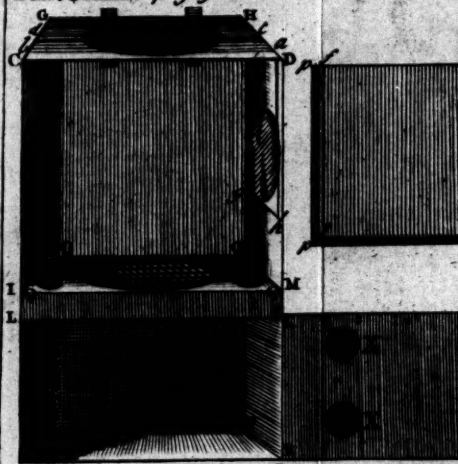
2. A full View of the same.

K, H, X. The Segment for holding the Neck of the Retort.

I, K, X. A Pot 12 Inches wide, and 5 deep.

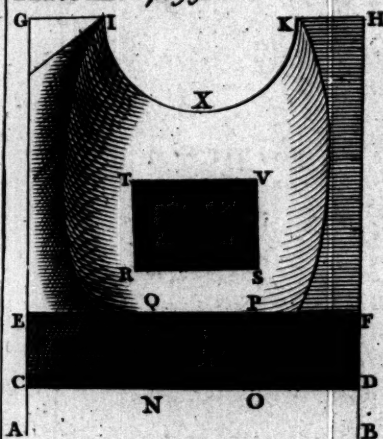
J. M. g. m. f. p.

Plate XIII. p. 589

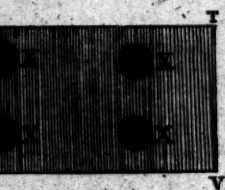
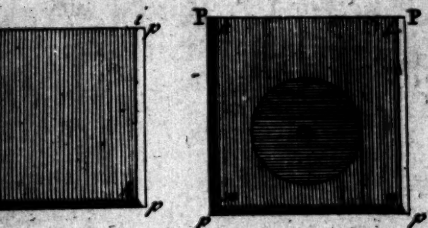


The first or Wooden Furnace
 AB. One Side of the Square base 9 Inches
 ABEF. The Square Base.
 ACBD. The Furnace is 14 Inches high.
 AIBK. The Grate 5 Inches high.
 ILKM. The Partitions 1 Inch thick.
 LCMD. The upper Part of the Furnace 8 Inches high.
 P P. Around hole 5 Inches wide for supporting
 QQQQ. Four round holes, each 1 Inch wide, of the Heat to the upper Part of the Furnace.

Plate XIV. p. 590.



The Second Furnace
 ACBD. Iron Feet 19 Inches long.
 CNOD. Bottom of the Furnace 17 Inches wide.
 CGHD. A hollow Iron Cylinder placed on...
 14 Inches high.
 ELMF. The Grate consisting of a round Rim and...
 supported by EF.
 ELMF. Its Rim 3 1/2 broad.
 ECDF. Distance from the bottom 4 Inches.
 NOPQ. Door of the Ash hole 4 Inches high and...



en Furnace .
e 9 Inches .

igh.

urnace 8 Inches high.
for supporting a Retort &c.
Inch wide. for the Passage
of the Furnace.

f g h i. A Square hole in the upper Part of side
B D H E. into which is plac'd a square board that fits
into it, mark'd with the same Letters.
f p. g p. k p. i p. The Edge of this board plan'd away to half
its Thickness, in order to be put into the hole g h i d. which
is 9 Inches and 5 wide, when a Cucurbit is us'd.
k l m n. Another square board like the former, with a round
hole o to be us'd in distilling with
a Retort.

f. g. k m. each 6 3/4 Inches.

R S T V. The Door of the Grate.

X X X. Four round holes in it for admitting Air to the Fire place

Z. Registers of Wood to fix therein for governing the Fire

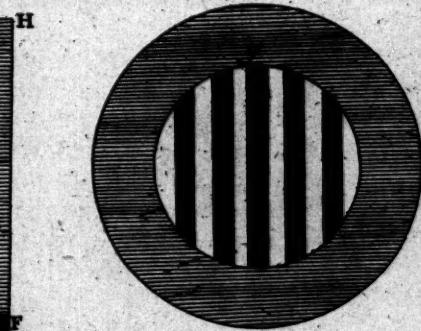
Ct. Da. Gd. Hc. Two folding Doors cut away in the Middle

so as when shut to leave a hole 2 1/2 Inches wide.

g. An earthen Pan us'd on this Furnace.

r. Its handle.

s. s. Its feet.



urnace

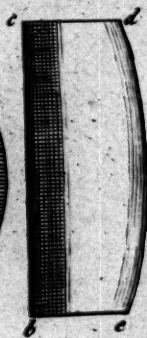
Inches wide.

placed on..... C N O D 19

ound Rim and Iron bars

Inches.

is high and 6 wide.



Q R P S. The Distance from the Top of the Grate 3 Inches.

R S T V. The opening into the Fire Place 6 Inches wide

and 4 1/2 high.

I L K M. The Ellipsis whose greater Axis..... L M I K. is

10 Inches.

b c d e. The wooden Model us'd in its Structure.

a. A Side View of the Register.

z. A full View of the Same.

K H X. The Segment for holding the Neck of the Retort.

I K X. A Pot 10 Inches wide, and 5 deep.

J. M. g. n. s. p.

less degree of fire is disorderly applied in the same operation. We know likewise, that an alteration in the degree of heat may so alter the subject, that it shall no longer remain the same with respect to another degree of heat, that would otherwise have produced a determinate effect; which has often proved a pernicious error.

4. Hence, in the building of furnaces, we must always regard, (1.) The quantity of fire which the fire-place ought to receive, contain and support. (2.) The matter of the fuel to be used for the purpose. (3.) The degree of heat required in every operation; since, in the same fire-place, the same quantity of the same fuel may produce different degrees of heat. Whence, (4.) the air must always have easy access to the fire-place; and the force with which the air tends to the fire, under the form of wind or blast, should be computed. So likewise the various states of the atmosphere, with respect to weight, moisture, heat and cold, should be considered; for fire burns the fiercest in frosty weather, whilst the air is driest, and shewn by the barometer to be the heaviest. (5.) The air-vent from the fire-place should be principally regarded; for, if this be wide, the air here diffuses, and loses it self; or acts but little upon the subject, where its force ought to be collected. These are the chief foundations required in the building of furnaces. And this being premised, I proceed to describe the structure of my own little furnaces, used in my courses; being such as are necessary for those who would perform all the chemical operations.

5. I shall begin with my simplest furnace; which I invented forty years ago, when I practised chemistry in no large study, where there was only one little chimney, and where I required several furnaces at once. Make a hollow prism, with a square basis, of sound dry oak, nine inches wide, and four-
The first, or simplest furnace.
 teen high; fix into it a square piece of wainscot, an inch thick, five inches
See plate XIII.
 from the basis, so as thus to divide the furnace into two parts; the lower whereof, being five inches high, serves for the fire-place; and the upper, eight inches high, is to receive the retort, or cucurbit, for distillation. This piece of wainscot, serving as a partition, must have a round hole in the middle, five inches over; where the round bottom of the vessel is to rest. Besides this large hole in the partition, there must be four other round holes made in it, each an inch in diameter, that the fire may rise freely from the fire-place into the second story. On one side of the fire-place, there must be a door, going upon hinges, and equal in dimension to the whole side, or nine inches broad, and five high, so as to open easily, and shut close. The whole internal surface of this fire-place must be lined with plated iron or copper, to defend the wood from the fire. The door is to have four round holes made in it, each of them an inch in diameter, to admit the external air; and these holes are to be fitted with four cylindrical stoppers, easy to take in and out, so as to regulate the fire, by admitting or excluding the air. This door must be made of seasoned wood, and contrived to shut extremely close. In the upper part of the furnace, the side above the door must have a square hole cut in the middle to the top of it, four inches and a half over; the inner edge of which is to be cut away, on its three sides, to
half

half the thickness of the board, or to the breadth of half an inch; and to the internal sloping surface about this hole, a plate of wood must be so fitted, as to make a joint; this being of use to shut the side of the furnace close, when we design to distil, digest, or exhale, in a cucurbit, phial, or evaporating glass; whereas the plate of wood being taken away, fits the furnace for distillation by the retort. There must also be another similar plate of wood, with a hole in the middle, two inches and a half over, so as to let the neck of a retort pass through it, when fitted into the square hole, instead of the former. A pair of folding-doors should also be made, to serve as the flat top or cover of the furnace; the middle part of which doors must be cut into a round hole, of five inches diameter, to let out the neck of the cucurbit, or bolt-head, used in digestion. In the last place, there must be a round, flat piece of wood, six inches in diameter, to cover this upper orifice, when the furnace is used for distilling by the retort.

6. In order to work this furnace, we must be provided of a square, flat-bottom'd earthen pan, standing upon three feet, about half an inch high; the height of the pan being, from the bottom of the furnace to its upper rim, three inches and a half: at the bottom of this pan, a little sifted ashes must be lightly sprinkled, a quarter of an inch thick; then an ignited coal of *Dutch* turf, first burnt till it yields no more smoke, is to be laid upon this bed of ashes, and covered by sifting more of the same ashes lightly upon it; whereby an equable, moderate heat may be kept up for near twenty-four hours. The less ashes the burning coal is covered with, the more heat it yields, but the sooner it expires. This furnace works without yielding any smoke, or disagreeable smell; and affords so gentle and equable a heat, that, I believe, eggs may be hatched by it; tho' it may be raised high enough to make water boil, or higher: and consequently will commodiously, safely, and at small expence, perform all kinds of digestions, and distillations of aqueous and spirituous liquors, volatile alkaline salts, and volatile aromatic salts, or tinctures, exhalations, &c. I have even distilled *Glauber's* spirit of nitre, and spirit of salt; in this furnace; which is therefore a fit furnace for students.

*The second
furnace.*

*See plate
XIV.*

7. If a furnace be required, capable of giving a stronger heat, so as to distil in sand, I judge the best contrivance for a student in the art, is the following: and as portable furnaces are the most commodious, on account of leaving the chimney of the laboratory free, I shall here describe one of the portable kind. Let a hollow cylinder be made of thin iron plate, seventeen inches in diameter, and nineteen inches high, the lower end to be closed, and the upper end open; let the bottom be supported with three iron feet, twelve inches long, and let the iron-bottom be covered on the inside with a copper-plate, lest the salt in the ashes should otherwise soon corrode the iron. Let a grate be fixed in this cylinder, so that the upper surface thereof, being parallel to the base of the cylinder, may rise four inches above it. Let the grate be surrounded with a flat ring of plated iron, three inches and a half broad. Let the bars of the grate be flat, half an inch wide, and set at the distance of an inch from each other. This iron rim of the grate must rest

rest upon three iron pins, sticking out on the inside of the furnace, to fix the grate. Let the ash-place be fitted with an iron-door, four inches high, and six inches wide, to move upon hinges, and shut exactly close. At the height of three inches from the upper surface of the grate, let the bottom of the fire-place begin; and make the whole six inches wide, and four inches and a half high. Next, describe an ellipsis, with the distance of fifteen inches between the foci, and a perpendicular of five inches, from the focus to the circumference; and make a wooden model of half such an ellipsis, cut off at the foci. This model is to serve as a core, in forming the cavity of the furnace, by adjusting fine brick-work, in correspondence to the figure made by revolving such a model about its axis; and thus leaving but little space between the joinings, to be exactly filled up with mortar. But before this is done, let a stopper be made for the fire-place, of the same iron plate, and of the same cylindrical surface, and internal substance, as the furnace it self: the outer rim of this stopper should over-spread the opening of the fire-place, an inch every way; whilst the internal surface exactly coincides with the internal surface of the furnace, when the stopper is applied. The top of the cylindrical part of the furnace must be cut into a hollow, three inches wide, and two deep, on the same side with the door, in order commodiously to receive the neck of the retort, in distillation. Lastly, an iron pot must be fitted into the upper opening of the furnace, and fixed so close and strong, with brick and mortar, that the work may neither crack, nor let the fire escape; but, near the upper rim of this pot, there must be left in the brick-work, four vent-holes, made in the form of crescents, an inch over in their widest part, and two inches in their curvature, to discharge the smoke, and make a draught of air to animate the fire occasionally. And thus you will have a furnace fit for distilling by the cucurbit, retort, or bolt-head; and being portable, it will also serve for many other operations.

8. The third furnace, which no laboratory can be without, is a *Balneum Mariae*, made like the two former; excepting, that the distance from the surface of the grate, to the bottom of the cylindrical copper-vessel, is only eight inches. But the copper-vessel it self, to be used for the *balneum*, and fastened in brick-work at the top of the furnace, is twelve inches deep; and in its upper part has an horizontal rim, an inch wide, whereby it hangs, and is supported by the furnace: and, above this flat rim, rises a perpendicular edge, an inch high. To this furnace belongs another vessel, capable of entering the former, without touching the sides and bottom thereof by an inch; and rising five inches above the breast of the furnace. This vessel has a rim fixed on its outside, eleven inches from the bottom; which rim turns a little downwards, where it is broad enough to cover the mouth of the other vessel, so as to close it by wrapping over it. On one side of this broad rim of the second vessel, there is a pipe, thro' which water may be supplied to the first vessel. The neck of this second vessel is fitted to receive a still-head, whose pipe entering a pewter-worm, passing through a worm-tub, makes a proper apparatus for distilling in *balneo Mariae*: and thus likewise alcohol may be distilled, by using the particular tall head above described, for the purpose.

The

The first of these two vessels may likewise be turned into a still, by clapping on an alembic head, and working with a worm, and its refrigeratory so as to perform with it all the common distillations in any degree of heat up to two hundred and twelve.

Fourth furnace.

See plate XVI.

9. A fourth furnace is also required in a laboratory, to raise a strong fire for the melting of bodies not easily fused: the best furnace for which purpose, is thus made. Let a stone-arch be built three feet high, as a basis whereon to raise this furnace so that the operator may commodiously look into the fire whilst he stands erect; then make an ash-hole five inches high, upon this basis, and over that fix in a grate, consisting of iron-bars near an inch thick, and set at about an inch distance from each other. Let the bottom of the grate, and the ash-hole, be of a circular figure, twelve inches in diameter, and build up the cylinder six inches above the grate; then raise upon it a parabolic cone with an axis of eight inches and its lower ordinate of six; whence, the *latus rectum* will be four inches and a half, and the *focus* one inch and an eighth of an inch from the *vertex*. Over this parabolic cone of six inches, build a cylindrical chimney of three inches diameter, and two feet high. In the front of the fire-place, two inches above the grate, make a door five inches wide and six high, and arch it at top with the arc of a circle twelve inches in diameter. At the height of an inch above the arch of the door, make a conical hole in the furnace, two inches wide on the outside, that the operator may look downwards into the fire, when any thing is melting; and let a stopper be exactly fitted to this opening. The furnace must be built with good brick and terras, and have its sides five inches thick; the internal surface thereof being laid smooth with cement: and thus, when once heated, it will raise a most violent fire, especially in its middle and upper part, as easily appears from geometry. The iron-door must be made to shut very close, by being received into a niche left for the purpose, in the side of the furnace; and the bottom of the ash-hole should be laid with an iron-plate, to secure matters that may happen to fall through.

The fifth furnace.

See plate XVII.

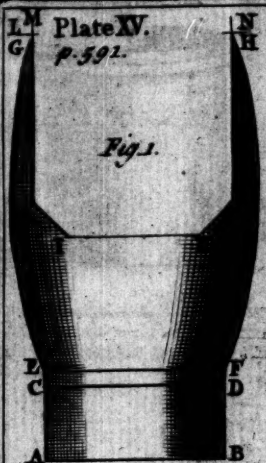
10. A chemical laboratory must also necessarily have a particular furnace for distilling the mineral acids, as those of sea-salt, nitre, alum, vitriol, &c. After several trials, I judge the following fittest for the purpose. Upon the pavement of the laboratory, under the chimney, build up a parallelopiped twenty inches broad in front, and thirty-eight inches long; let the cavity be twelve inches wide in front, and twenty-two inches long, which gives the thickness of the wall; let the parallelopiped be raised eleven inches high; make a door-way in the middle of the front, rising eleven inches from the ground and four inches wide, leaving an indenture on the front of the furnace to receive an iron-door, and let it in close occasionally. This part of the apparatus regards the ash-hole, and air-vent of the furnace. Instead of a grate, here use prismatic iron-bars, an inch wide and fourteen inches long; placing them an inch asunder, parallel with the breadth of the ash-hole. Now describe an ellipsis in the upper cavity, upon this parallelopiped, with the foci twenty-two inches asunder, and the transverse diameter of twelve inches; whence, the breadth of the fire-place, will, at both ends, be about

ten

Furnace
No.

meter is 12 inches
11.8 inches high
to cone

the work is 12 inches



A brass Vessel to s
way of Bath or for
mark'd with the Lette

The third Furnace
 AB. The Ash-hole 10 Inches wide.
 AC. Its Height 6 Inches.
 EC. Thickness of 3 grate 1 Inch
 EI. Distance from the Grate to the
 bottom of the Vessel 8 Inches
 IG. Its Height 18 Inches.
 LG. Its Rim 1 Inch broad.
 GM. Its erect Rim for admitting the
 Rim of the Vessels Fig. 3. &c.
 EGFH. Internal Cavity of the Furnace.

Fig. ML
into the
Rim K
into the
ahole p

Fig. 3. p. 585.



A brass Cover n
MOGH of Fig.
R.S. Its Handle
RSTV. The m
as to terminate
for receiving the

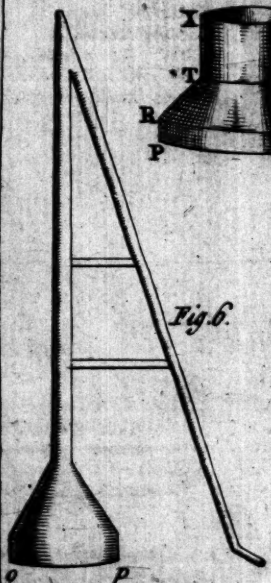
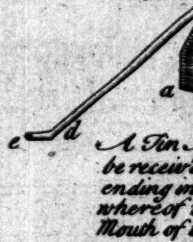


Fig. 6.

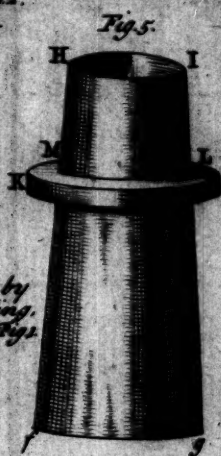


A Tin
be receiv
ending in
where of
Mouth of

The Tin Membr
op. being receiv
distilling Alcoho
in the Vessel f I.



*Vessel to serve by
Bath or for distilling,
with the Letters of Fig. 2.*

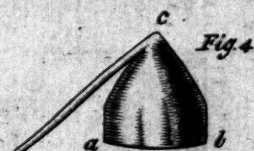


*fg ML. A Vessel to be admitted
into the Vessel GK. of Fig. 1; its
Rim KL. being made to be receiv'd
into the Rim MO of Fig. 2. KL. having
a hole for pouring water into GK.*

*Trag Cover whose Rim PQRS fits the Rim
GH of Fig. 2.*

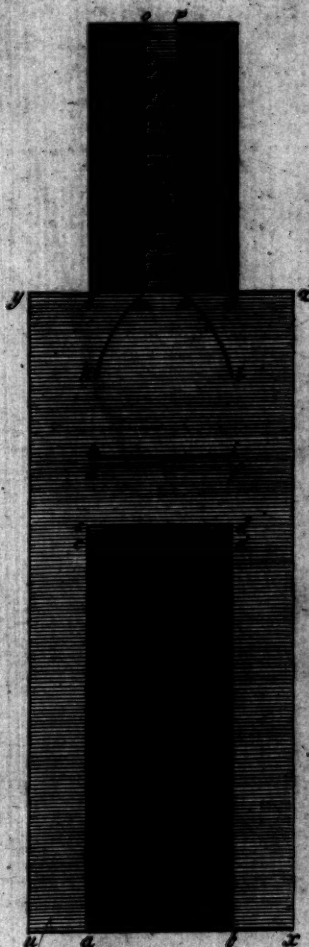
3. Its Handles

*TV. The middle of the Cover so form'd,
to terminate in a Cylindrical Neck TVY.
receiving the Alembic.*



*A Tin Alembic, whose Rim ab may
be receiv'd into the Rim XY: its Head
ending in a Beak cde. the Extremity
whereof may be insert'd into the
Mouth of the Worm.*

*Tin Alembic of Plate II. whose Rim
being receiv'd into III Fig. 5. serves for
Ulling Alcohol: the Spirit being contain'd
Vessel f I.*



The fourth melting Furnace

abcd. The Stone Base.

cdef. The Ash-hole.

efgh. The Grate.

ab. cd. ef. hi. The Diameter 12 Inches.

ht. il. The Focus to kl. 6 Inches high.

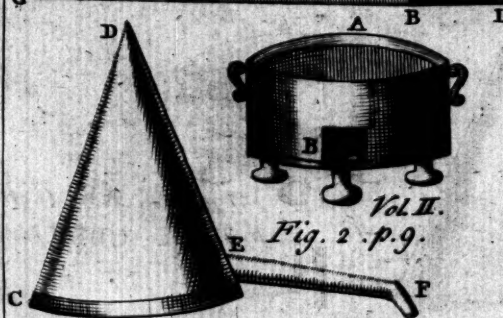
kml. The parabolic Cone

mn.op. The Funnel

*auy. bz. 23 The Stone work 5 Inches
thick.*

Plate XVII.

Fig. 1. p. 592.



*Vol. II.
Fig. 2. p. 9.*



ABCD The Fifth Furnace.

AB. It's Breadth 20 Inches.

ACBD. Height 38.

C AHIB. Each 8 Inches long.

HL the Ash-hole 4 Inches broad.

HKIL. It's Height 11.

KMLN. the Fire place door, distant from it 3 Inches.

MNOP. It's Breadth 7 inches.

MONP. It's Height 9.

BGDE. Length of the Furnace 38 inches.

QRS. An Opening for placing the long necks.

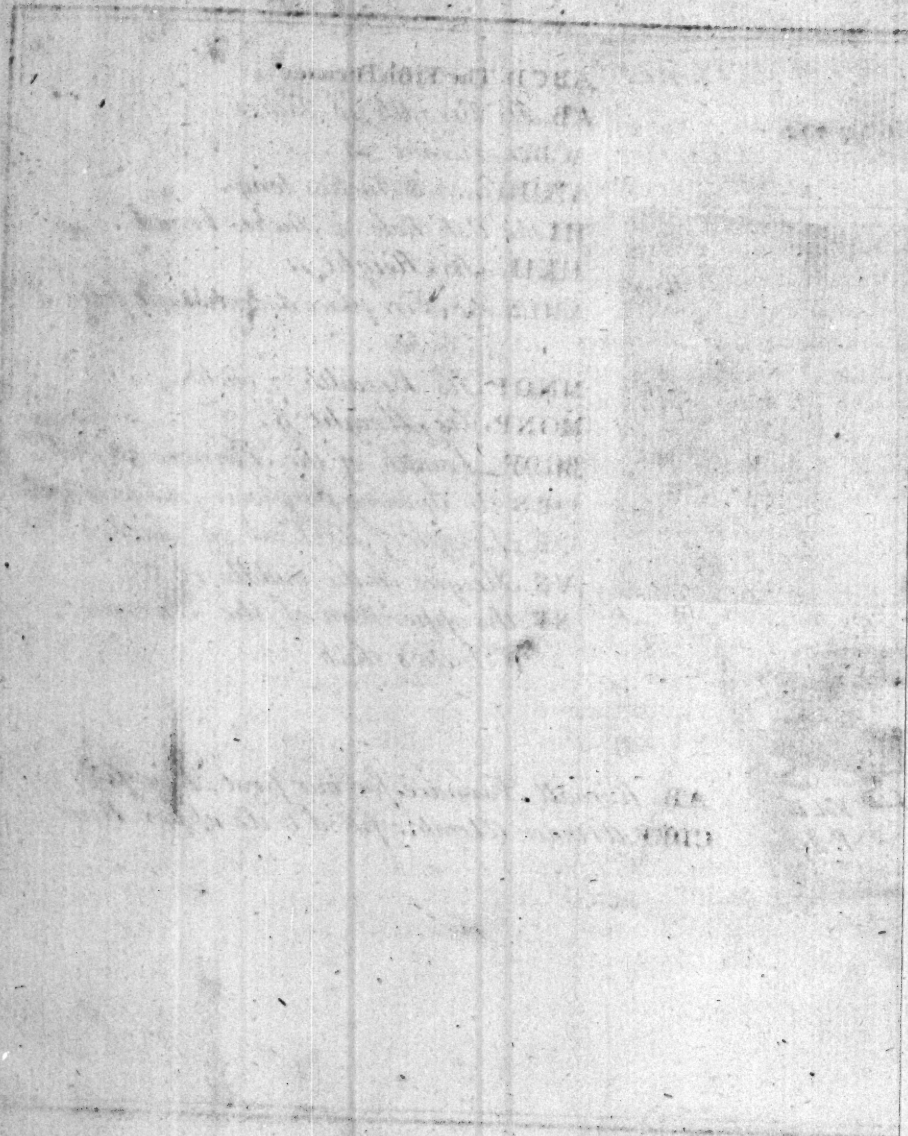
QR. Length of its Limb 20 Inches.

VS. Height in the middle 12.

SF. the upper Wall of the Furnace, 6 Inches thick.

AB. A small Furnace for our first Process.

CDEF. A Pentter Alembic fitted to it's upper Rim.



ten inches. Next let there be a cavity formed, of this elliptical figure, four inches and a half deep on the inside; and complete the external part in a parallelopiped form. In the front-wall, immediately over the ash-hole, make a door-way to the fire-place, seven inches wide, and nine inches high; and let the bottom edge of this door-way slope an inch and a half downwards, that it may be exactly fitted with an iron-door: let the lower line of the door be three inches above the upper line of the ash-hole. In the other longer side, there must be an arched opening, with its lower limit rising ten inches above the grate, and being twenty inches long, and twelve inches high; and the elliptical arch, with its foci twenty inches asunder, and its transverse diameter twenty-four. This opening is for the distilling vessels to be put in, and taken out at. On the internal side, opposite to this opening, at the height of nine inches above the grate, a ledge, of an inch and a half, must be left, to support the vessels employed in the distillation; and in the middle of the upper part of this wall, there must be a square hole, three inches wide, and two inches high, for the chimney. The upper elliptical arch must next be made; whose vertex is to rise twenty-one inches above the grate, the axis of the ellipsis twenty-two inches, and the transverse diameter ten. Let such an arch therefore be struck, by revolving such an ellipsis about its axis, reaching sixteen inches from the grate. When this furnace is used for distillation, two cylindrical, earthen long-necks, twelve inches high, and nine wide, having cylindrical necks five inches long, and three inches and a half in diameter, are to be placed horizontally, and parallel to each other; so that their bottoms may rest upon the ledge in the opposite wall; whilst their mouths lie parallel to the opening they are put in at; which opening is now to be perfectly closed up with brick and mortar, leaving the necks of the vessels sticking out, whereto earthen pipes being applied, and their other ends fixed into receivers, the operation may be thus begun. This furnace will raise a surprizing degree of heat; being, at the same time safe and easy to manage. It likewise directs all the force of the fire upon the subject to be distilled; and may easily be regulated by means of the ash hole.

II. The furnace for assaying is so well described by *Ercker* and *Agricola*, *Other furnaces here need-* that we need not mention it here; and the common still, with its worm, and worm-tub, is too well known to be insisted upon. So that here, at length, *less.* we finish the second part of our undertaking.



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